DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather within the Headquarters United States Air Force, Deputy Chief of Staff for Air and Space Operations (HQ USAF/XOW). The Air Force Director of Weather oversees the development and implementation of operational concepts, doctrine, policies, plans, and programs to provide effective environmental information for the Air Force, Army, and other agencies as directed by the Chief of Staff, United States Air Force (USAF). The AF provides environmental information to DOD Joint operations as directed by the Joint Chiefs of Staff (JCS) under the Unified Action Armed Forces (JCS Publication O-2) document. The Air Force Director of Weather interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Force Weather (AFW) Organization. AFW is a Total Force organization, employing the active forces as well as Air Force Reserve (AFR) and Air National Guard (ANG) weather personnel. The active component of AFW has recently completed reengineering to mirror the three levels of military operations--strategic, theater (operational), and tactical. The Headquarters, Air Force Weather Agency (HQ AFWA), a Field Operating Agency (FOA) reporting to HQ USAF/XOW, provides strategic-level weather information (global and synoptic-scale) to worldwide customers in addition to fulfilling some unique mission requirements (discussed later). HQ AFWA, located at Offutt Air Force Base (AFB), Nebraska, has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) at Asheville, North Carolina, and the Air Force Combat Weather Center (AFCWC) at Hurlburt Field, Florida. In addition, space environment operations have nearly completed the transition from the 55th Space Weather Squadron at Schriever AFB, Colorado, to HQ AFWA. Eight Operational Weather Squadrons (OWS) provide theater-level environmental information tailored to overseas theater Commander-In-Chief and/or Numbered Air Force (NAF) operations (Figure 3-DOD-1). Each OWS is designated as the forecast agency for a specific geographical area of responsibility (AOR) in concert with their associated NAFs or Theater's AOR. Continental United States (CONUS) OWSs are also responsible for CONUS regional weather information. OWSs provide theater-scale tailored environmental information to active duty as well as ANG units executing their Homeland Defense missions during Operation NOBLE EAGLE. They produce and disseminate terminal forecasts, weather warnings and advisories, planning and execution area forecasts, and other operational products to Combat Weather Teams (CWT). The CWTs, located at base and post level, take and disseminate local observations and provide mission-tailored forecasts and briefings at the tactical level based on centrally produced guidance. In addition to the active duty force, approximately 110 weather personnel serve as AFR individual mobilization augmentees assigned to various active AFW units at all levels. They typically train two days each month and for an additional two weeks each year. The ANG program consists of two distinct functions. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and provide weather information to Army National Guard and United States Army Reserve units as well as ANG flying

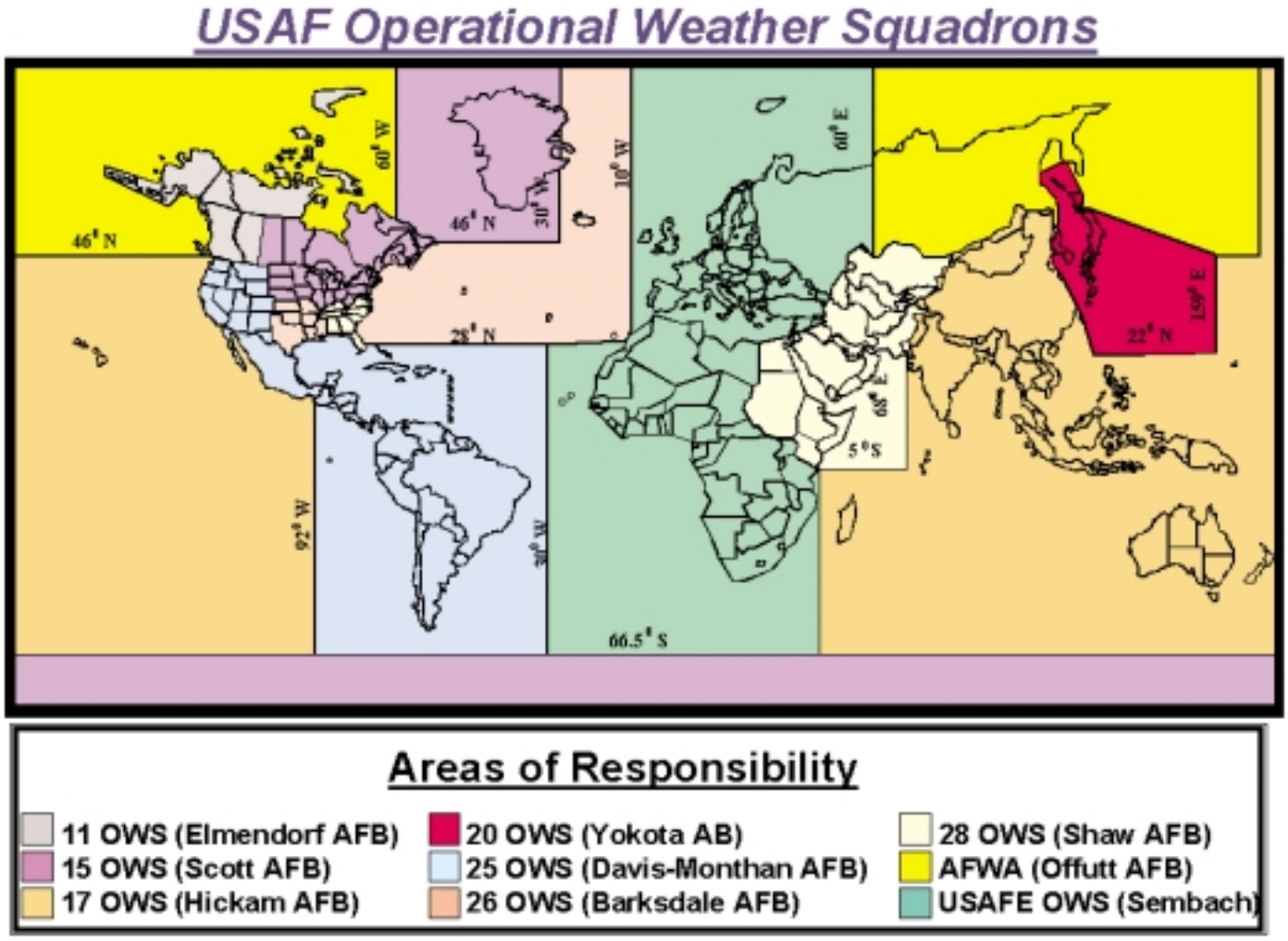

Figure 3-DOD-1. Areas of Responsibility for Air Force Weather's Operational Weather Squadrons.

units. The ANG operates the Weather Readiness Training Center at Camp Blanding in Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield support. Total Force AFW personnel enhance the unique global capability of ground and aerospace military operations, while indirectly assisting civil aviation by providing flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

To fulfill its global mission of providing timely, accurate, and relevant weather information, AFW maintains and continually improves on its five core processes: data collection, analysis, forecasting, tailoring, and dissemination. The following paragraphs provide more information on each of these areas.

Weather Data Collection integrates the spectrum of remote and fixed sensors into a single meteorological sensing and instrumentation approach for battlefield and in-garrison operations. Data collection in the space environment is discussed in the Space Environmental Services section.

AFW personnel take observations essential for effective military operations and for weather analysis and forecasting. Weather personnel at both Air Force and Army locations (fixed and tactical) make observations available to local users and transmit them to military and civil locations throughout the world via the Automated Weather Network (AWN). Upper air observations provide vital input to numerical weather analysis and prediction. United States and foreign rawinsonde reports are primary sources and are supplemented with military and civilian pilot reports. The Observing System 21st Century (OS-21) program will provide a much-needed, state-of-the-art, life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. The manual configuration is intended for tactical operations and continues the improvements begun under the Manual Observing System and Tactical Meteorological Observing System Modification programs. For remote surface observations, AFW purchased commercial off-the-shelf Remote Miniature Weather Systems (RMWS) to provide accurate real-time

weather information from forward unmanned locations. Special Operations Forces (SOF) used RMWSs widely and successfully in Afghanistan during Operation ENDURING FREEDOM, among other operations.

Weather radar data is a principal source of information needed to produce severe weather warnings. Within the CONUS, AFW uses the WSR-88D. DOD, the National Oceanic and Atmospheric Administration (NOAA), and the Federal Aviation Administration (FAA) operate and maintain the radars within CONUS, and the Air Force operates and maintains the overseas radars. Tactical Weather Radars (TWR), which provide a weather radar capability to worldwide military contingency operations, replace existing radars at deployed locations and at select fixed locations overseas.

The Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, is a vital source of global weather data used by combat operations. On-board sensors provide HQ AFWA and the Navy's Fleet Numerical Meteorology and Oceanography Center with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, electrically charged particle fluxes, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses the Operational Linescan System to provide visible imagery to optimize distinction among clouds, ground, snow, and water. The DMSP also flies microwave temperature and moisture sounders (SSM/T and SSM/T-2). Processing algorithms convert the sensed data into vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data. The Block 5D-3 spacecraft were scheduled to begin service in 2002 with the launch of DMSP Flight 16. The new spacecraft will add several new capabilities: enhanced microwave imaging and atmospheric temperature/moisture sounding through the Special Sensor Microwave Imager/Sounder (SSMIS); new auroral boundary and electron density measuring capability through the Special Sensor Ultraviolet Spectrographic Imager (SSUSI); and profiles of upper-atmospheric temperature, electron content, and species densities through the Special Sensor Ultraviolet Limb Imager (SSULI).

AFW continues to participate in the refinement of requirements for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace the existing DMSP and NOAA polar-orbiting satellite systems beginning in approximately 2009 and is a joint DOD, DOC, and National Aeronautics and Space Administration (NASA) program. A new ground terminal system will also provide a direct readout capability for tactical users similar to that of the DMSP. AFW also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program planned for launch in CY 2005.

In addition to DMSP polar-orbiting data, HQ AFWA receives stored data from the DOC's Polar-orbiting Operational Environmental Satellite constellation and real-time high-resolution data from the DOC's Geostationary Operational Environmental Satellite (GOES) East and West, the European Union's Meteosat-7 geostationary satellites, and Japan's Geostationary Meteorological Satellite-5. HQ AFWA receives data files from Europe's Meteosat-5 and India's INSAT-1D geostationary satellites, as well as NASA's Tropical Rainfall Measuring Mission and QuikSCAT, via the Shared Processing Program.

To receive real-time visible, infrared, and microwave imagery and other non-imagery weather data from both polar-orbiting and geostationary satellites, the Air Force has developed and fielded the Small Tactical Terminal (STT). STTs are composed of antennas and portable processors, thus giving tactical users a survivable "first-in" source of meteorological satellite data.

The Air Force Reserve Command's 53rd Weather Reconnaissance Squadron (53 WRS), also known as the "Hurricane Hunters," provides another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially equipped WC-130 aircraft collect temperature, moisture, wind, pressure, and visually observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropsondes. They penetrate the eyes of tropical cyclones to provide the National Hurricane Center a very accurate center fix location as well as other meteorological parameters, including sea level pressure. In addition to the tropical cyclone reconnaissance mission, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible. For more information, see their web site at *http://www.hurricanehunters.com/*.

Analysis and Forecasting. HQ AFWA is the primary Air Force strategic production center for weather analyses and forecasts while the OWSs are the primary theater-scale production centers for Air Force and Army operations. HQ AFWA uses networked computer systems and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide conventional weather data are relayed to HQ AFWA and combined with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further process the data to construct models of the atmosphere and forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished at HQ AFWA with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed manipulation of satellite and conventional meteorological data to prepare forecasts and other environmental products.

HQ AFWA has organized forecast operations to achieve greater flexibility and focus production on its primary customers. Forecasts are generated in the agency's Global Weather Center Division, which consists of five production branches: Global Weather Center Production, Special Support Operations, Space Weather, National Intelligence Community Weather, and Meteorological Satellite Applications.

The Strategic Section of the Global Weather Center Production Branch produces tailored worldwide meteorological analyses and forecasts used by aviation customers. The branch also provides forecasts of CONUS low-level aviation hazards and hot backup to Aviation Weather Center and Storm Prediction Center. The American Forces Network Weather Center provides worldwide, broadcast-quality public weather services and planning forecasts through the American Forces Radio and Television Service to over 800,000 DOD and Department of State personnel and family members stationed overseas.

The Special Support Operations Branch (SSOB) provides worldwide mission-tailored forecasts to Joint SOF. The branch acts as a clearinghouse for unique data requests from the SOF customers; provides tailored meteorological information for end-to-end targeting operations to unified command, component, and national customers; produces long-range (4-8 day) forecasts for unified command, component, and national customers; and supplies the Nation's reconnaissance community with cloud-free forecast products. The SSOB is continually involved in worldwide military operations. Operation ENDURING FREEDOM highlighted the role of SOF forces in modern warfare. The SSOB provided these forces a myriad of products ranging from air refueling forecasts, to tailored meteorological satellite imagery, to tactical decision aids, distributing them via classified secure media. Additionally, the SSOB actively participated in the Homeland Defense mission through its operations with North American Aerospace Defense Command. By advising Operation NOBLE EAGLE decision-makers of mission limiting weather, they ensured alert aircraft maintained the highest state of readiness possible.
The Space Weather Branch provides worldwide general and tailored analyses, forecasts, advisories, and warnings for space weather phenomena that can affect military operations and National Intelligence Community activities. The branch provides products for agencies from all DOD Services using space weather measurements from a variety of ground- and space-based sensors. Data sharing and forecast coordination is performed with the NOAA Space Environment Center (SEC) in Boulder, Colorado. Due to the highly technical nature of precision-guided munitions, satellite communications, and modern guidance and radar systems, space environmental impacts are a key and growing field critical to military operations. The reliance on Global Positioning Systems (GPS) and their vulnerability to solar storms compel military planners and commanders to use space environmental information in all phases of combat. This was true in Operations ENDURING FREEDOM and NOBLE EAGLE as well as in routine daily operations.

The National Intelligence Community Weather Branch provides weather information to the classified National Intelligence Community. The branch produces detailed global cloud analyses and forecasts. Under this branch, the Special Projects Operations Cell provides worldwide mission-tailored planning and execution forecasts for National Intelligence Community agencies at the levels up to Top Secret/Sensitive Compartmented Information (TS/SCI) level. The branch serves as the focal point for HQ AFWA Special Access Program (SAP) requirements; ensures the National Intelligence Community and other SCI and SAP meteorological requirements are integrated into HQ AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to the National Intelligence Community; and interfaces with the DOD and National Intelligence Community regarding weather services and exploitation of weather information.

The Meteorological Satellite (METSAT) Applications Branch provides operational imagery analyses production, technique development, technology insertion, and product improvement. The branch produces rapid response tailored METSAT imagery and evaluation for DOD contingency operations and generates automated

METSAT imagery products for web-based distribution to DOD customers. The branch tracks and classifies tropical cyclones, using METSAT analysis, for the DOD Joint Typhoon Warning Center (JTWC) and the DOC National Hurricane Center; serves as the DOD focal point for volcanic ash plume detection, advisories, and trajectory forecasts; and provides hot back up for both JTWC satellite operations and the DOC's Washington Volcanic Ash Advisory Center. The METSAT Applications Branch produces worldwide snow and ice cover analyses to update and refine the Snow Depth database and also provides tailored snow depth and dust event analyses in contingency areas. During Operation ENDURING FREEDOM, branch imagery specialists provided high-resolution analyses of extensive dust storms in Central Asia. These storms potentially impact air, land, and sea operations; advance notice allowed mission planners to modify operations to maximize mission effectiveness. The branch also develops new capabilities to display and visualize satellite imagery on workstations and infuses state-of-the-art techniques into improved imagery analysis ensuring high quality customer products.

The recently completed Global Theater Weather Analysis and Prediction System (GTWAPS) program has improved interaction of the strategic, OWS theater-level, and CWT tactical-level forecasting systems. The key software component of the GTWAPS program is a theater analysis and forecast model--Mesoscale Model version 5 (MM5), which provides fine-scale forecast data with improved accuracy. During Operation ENDURING FREEDOM, HQ AFWA initiated various model window locations and resolutions as mission requirements dictated. The highly responsive nature of the MM5 and the way HQ AFWA employs it permitted new contingency windows to be operational within hours. Advancements in cloud modeling have enabled GTWAPS to produce high-resolution products that became a mainstay of weather data during Operation ENDURING FREEDOM. Used by Predator Unmanned Aerial Vehicle (UAV), Global Hawk UAV, and space-based reconnaissance operators, these products allowed decision-makers to choose the most effective reconnaissance platform to maximize mission effectiveness. MM5 is routinely provided by AFWA to National Centers for Environmental Prediction (NCEP), where it is utilized as a backup to their ETA model.

On-going modernization initiatives at HQ AFWA include the Reengineered Enterprise Infrastructure Program (REIP), Cloud Depiction and Forecasting System (CDFS) II, the Space Weather Analysis and Forecasting System (SWAFS), and the Weather Data Analysis (WDA) program. REIP closes the Detachment 7 facility at Tinker AFB and relocates/reengineers its functions of alphanumeric data collection, processing, and dissemination (to include the AWN) to HQ AFWA. CDFS II brings major software and hardware modifications at HQ AFWA to upgrade weather satellite data and cloud analysis and forecast processing and satisfy forecasting requirements. CDFS-II will double the horizontal data resolution of METSAT data and reduce its overall latency throughout each hemisphere by integrating the available suite of geosynchronous METSAT data into processing. SWAFS will integrate additional space weather data sources and execute next-generation space weather models for DOD and National Intelligence Community operations. WDA will continue the modernization of the HQ AFWA Strategic center as a component of the Air Force Weather Weapon System (AFWWS). The reengineered HQ AFWA strategic center will provide component-based and standards-compliant hardware, software tools, a central data cloud, and a classified processing environment to modernize the AFWWS communications and data processing infrastructure. WDA provides a significant increase in the database capacity and capability by standing up Joint DOD-approved METOC database segments that will begin an era of Common Operating Environment compliance and interoperability among data sharers.

OWSs provide theater-scale battlespace forecasts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; and airfield forecasts and warnings for Air Force and Army installations within their AOR. Their primary tool is the OWS Production System, Phase II (OPS-II), used to ingest data and strategic center information and create and disseminate theater-scale products.

Product Tailoring/Warfighter Applications. Progressive focusing and tailoring of weather information is the heart of the reengineered AFW organization, leading to individual mission-specific information provided at the CWT level. An example of specific mission tailoring performed for an emerging system still in testing is the Global Hawk high-altitude reconnaissance system and the turbulence forecasts provided by the weather personnel.

The Forecasting System 21st Century (FS-21) program is the vehicle for providing necessary computer hardware and software throughout all levels of AFW (HQ AFWA, OWSs, and CWTs). The OPS-II is the backbone of the OWS production system. This hybrid system of databases, servers, and workstations, provides the computer hardware and software necessary for OWSs to produce and disseminate forecast products to CWTs.

The New Tactical Forecast System (N-TFS) provides garrison and deployed CWT personnel the meteoro-

logical tools necessary to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, command and control, and support forces worldwide. N-TFS provides weather personnel the ability to use the same system in "peace and war," thus providing a robust "first in" and sustainment weather forecast capability to combat weather units worldwide. Additionally, N-TFS ingests data from Air Force observing systems and observations from indigenous sources, which then gets forwarded to OWSs/HQ AFWA for further dissemination and incorporation into the central data cloud. Data from the N-TFS, combined with satellite imagery from the STT, provide the essential capability required for deployed weather units to meet operational mission requirements.

Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools, which continue to be integrated into command and control systems and mission planning systems, include Target Acquisition Weapon Software (TAWS), Night Vision Goggles Operations Weather Software (NOWS), InfraRed Target Scene Simulation (IRTSS), and Joint Environmental Exploitation Segment (JEES), all modular programs developed by the Air Force Research Laboratory (AFRL) with additional assistance from the Navy's Space and Naval Warfare Systems Command, the Navy Research Laboratory and the Army Research Laboratory. TAWS provides a mission planning tool to combine platform, weapon, target, background, and weather impacts to depict three-dimensional weapon acquisition and lock-on range versus time. NOWS (soon to be integrated into TAWS) provide illumination and environmental impacts on night vision goggles used by aircrews, naval, and ground forces to execute nocturnal mission profiles, including search and rescue. IRTSS uses detailed terrain information and multi-spectral imagery with TAWS processing to generate forecast target scene images for mission rehearsal. JEES uses environmental data with TAWS modules to automatically generate mission impact forecasts for large scale planning efforts such as Air Tasking Order preparation. JEES, TAWS, NOWS, and IRTSS integrate environmental impacts into the Mission Execution Forecast for Command and Control and Mission Planning Systems from zero to 48 hours prior to mission execution. The TDA program continues to add weapons systems, targets, and operational features at the request of operational customers from all three services. During Operation ENDURING FREEDOM, the WarWeather program provided additional targets requested specifically for application with TAWS and NOWS in operations.

Dissemination. AFW dissemination employs a variety of media to meet the needs of its worldwide customer base. High-speed communications between large DOD and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of these data to the OWS facilities. Forecaster-developed products and gridded data sets are distributed from HQ AFWA via the Communications Front-End Processor to base and post weather stations worldwide using dedicated 96-baud circuits. AFW will continue replacing these dedicated circuits in FY 2002 with commercial K -band broadcast satellites over the CONUS, Europe, and the Pacific using the Very Small Aperture Terminal (VSAT), saving significant communications costs by eliminating the network of expensive landlines to each weather station.

Alphanumeric data including surface, upper-air, and aircraft reports are collected and distributed via the AWN, VSAT, and the DOD's Non-Secure Internet Protocol Router Network (NIPRNET). The AWN consists of dedicated circuits ranging from 74-baud to 56kbps linking DOD, national, and international facilities worldwide, as well as sophisticated data collection, message creation, and dissemination software. Data are also received from DOD-operated High Frequency (HF) radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization channels. The Automated Digital Weather Switch at Tinker AFB, Oklahoma, to be transitioned to HQ AFWA in FY 2002, receives alphanumeric weather data, parses them according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end users over: (1) the same dedicated circuits, (2) NIPRNET, and (3) satellite broadcast facilities. The High Frequency Regional Broadcast (HFRB) system was terminated in FY 2002 and replaced by current technology communications equipment that are more reliable, satellite-based, and worldwide-capable.

AFW operates a website on the NIPRNET known as the Joint Air Force-Army Weather Information Network (JAAWIN). JAAWIN provides worldwide access to numerical model forecast graphics, satellite imagery, and text bulletins. Additional products are available to classified customers via the JAAWIN-Secret (JAAWIN-S) and JAAWIN-Sensitive

Compartmented Information (JAAWIN-SCI) capabilities.

An additional means of making tailored weather information available to DOD customers includes the Joint Weather Impacts System (JWIS). JWIS provides a link to weather information from both Air Force and Navy sources for use by command and control systems and applications. AFW successfully demonstrated JWIS during Joint Expeditionary Force Experiment 2000 and integrated an initial capability into the Combined Air Operations Center-Experimental in 2001.

Finally, HQ AFWA continued to enhance its presence on the Air Force Portal, an initial "one-stop gateway" capability established in 2001 to provide weather and other information to any Air Force user or activity. HQ AFWA will continue expanding this capability in FY 2003.

Unique Requirements. A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers as well as operational units. To fulfill this requirement, designated AFW personnel serve as part of the staff of operational Air Force, Army, and joint force units. In this capacity, AFW personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. Products and data are tailored to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations. This effort helps ensure that Air Force, Army, and joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission specific requirements.

Army weather requirements are completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. AFW units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be pertinent to and directly usable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observers to all command levels identified above. The Army Forward Area Limited Observing Program and the Army artillery meteorology program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs including a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological information to the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range, which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force provides environmental information to the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, Republic of the Marshall Islands, and other DOD research and test facilities.

The Air Force and Navy operate JTWC, which moved to Hawaii in 1999. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees longitude to the East Coast of Africa in both hemispheres.

The Air Force furnishes environmental information to DOD Special Strategic Programs, the President and Secretary of Defense, the National Military Command System, and the National Security Agency. Tailored environmental products are disseminated to these customers worldwide.

The Air Force also provides agrometeorological output to the United States Department of Agriculture's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation as well as trafficability and rudimentary flooding estimations.

AFCCC provides climatic data and specialized products to the Air Force, Army, and other government agencies. Typical climatic information satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects, quality assures, and applies worldwide surface and upper air observations, satellite derived soundings, numerical model output such as global gridded surface and upper air model data, a global three-dimensional cloud analysis (real-time cloud analysis), a global analysis of snow cover, and other specialized environmental data sets. AFCCC produces standard climatic summaries of meteorological phenomena for points worldwide. Examples of these standard products include the Operational Climatic Data Summary and the Wind Stratified Conditional Climatology. Analysts are also available to produce tailored prod-

Figure 3-DOD-2. Solar optical and radio telescopes at Ramey, Puerto Rico and Learmonth, Australia (lower left).

ucts for which no standard product exists to meet specific customer requirements. AFCCC employs the Atmospheric Slant Path Analysis Model to produce vertical profiles for any point around the globe for any time since 1987. Modeled climatologies are produced using the Advanced Climate Modeling and Environmental Simulations model. AFCCC is co-located with the National Climatic Data Center to facilitate cooperation and data exchange.

The Air Force Director of Weather is the DOD Modeling and Simulation Executive Agent for the Air and Space Natural Environment. The director executes his responsibilities through OL-M, HQ AFWA, located in Asheville, North Carolina. The Executive Agent is responsible for ensuring modeling and simulation developers and users have the tools, infrastructure, and databases necessary to represent the air and space environment rapidly, thoroughly, accurately, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence. OL-M sponsors relevant research and development and fields technology at AFCCC-the designated operational center providing tailored atmospheric data for modeling and simulation. OL-M also sponsors ongoing research in cooperation with the National Geophysical Data Center and the Defense Modeling and Simulation Office (DMSO) to develop a similar capability to provide tailored, on-demand representations of the space environment.

SPACE ENVIRONMENTAL SERVICES.

HQ AFWA is the DOD focal point for space environmental information and participates with NOAA in the operation of its SEC. Many DOD systems are affected by space weather phenomena that occur in the near-Earth environment. Space weather impacts fall in three general categories: electromagnetic radiation, high-energy charged particles, and electrically charged particle clouds. HQ AFWA provides a suite of automated and manually tailored space weather products to the range of customers susceptible to these impacts.

Sources of Space Environmental Information. A variety of ground- and space-based space weather data is available to forecasters providing information for space weather operations.

HQ AFWA operates a network of solar optical and radio telescopes at Sagamore Hill, Massachusetts; Ramey, Puerto Rico; Holloman AFB, New Mexico; Palehua, Hawaii; San Vito, Italy; and Learmonth, Australia. These systems provide observations of solar

phenomena at optical and radio wavelengths (Figure 3-DOD-2).

A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. AFW manages 15 automated Digital Ionospheric Sounding Systems (DISS) to provide measurements of disturbances in the ionosphere. The Jet Propulsion Laboratory also operates a complementary global network of sensors providing ionospheric data and the United States Geological Survey (USGS) operates a network of magnetometers located primarily in the Northern Hemisphere. The USGS data provides indirect measurements of the strength of ionospheric and magnetospheric electric currents, which create their own magnetic field superimposed upon the Earth's magnetic field. HQ AFWA receives these data from the SEC.

The GOES meteorological satellites provide real-time solar X-ray, electrically charged energetic particle, and geomagnetic data, made available through the SEC. DMSP, NOAA, and other DOD geostationary satellites provide additional energetic electrically charged particle data in low-Earth and geosynchronous orbits. Additionally, AFW leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data.

A number of additional sensors or improvements to existing space weather sensors are planned. The Solar X-Ray Imager (SXI) recently went into orbit aboard GOES-12. The SXI monitors solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum (Figure 3-DOD-3). AFW expects the first Solar Radio Burst Locator to become operational in 2002 to provide radio wave measurements of the Sun while also mapping certain solar phenomena blocked from optical view by cloud cover. HQ AFWA has additional improvements scheduled for the optical telescopes as well as for the ionospheric sensors.

HQ AFWA uses a suite of space weather models to specify current solar or global characteristics of space weather where observations are not available and to assist in forecasting future conditions. These models use available observations and include both climatology-based and physics-based algorithms. Some of the products created with these models include the Single-Frequency GPS Receiver Error maps (Figure 3-DOD-4), UHF Satellite Communication Scintillation maps (Figure 3-DOD-5), HF Illumination maps (Figure 3-DOD-6), and Radar Auroral Clutter maps. These products help warfighters determine where space weather is impacting their mission.

More detailed descriptions of both the available observations and current models are available in Chapter 2 of the *National Space Weather Program Implementation Plan*, Second Edition, available from the Office of the Federal Coordinator for Meteorology.

Mainstreaming Space. AFW continues its FY 2001-initiated effort to "mainstream" space weather for both providers and users. DOD's increasing reliance on space weather-affected systems, continuing expansion of operations into space, and the Air Force's designation as executive agent for space indicates space weather will become increasingly important. AFW will treat space weather initiatives the same as it does terrestrial weather initiatives. Once mainstreamed, the spectrum of weather information users should think of space weather as quickly as they do terrestrial weather. The AFW goal is to create a seamless, real-time depiction of the entire natural environment from the mud to the sun by planning, programming, and budgeting for space weather initiatives following the National Space Weather Program and National Security Space Architect's space weather architecture.

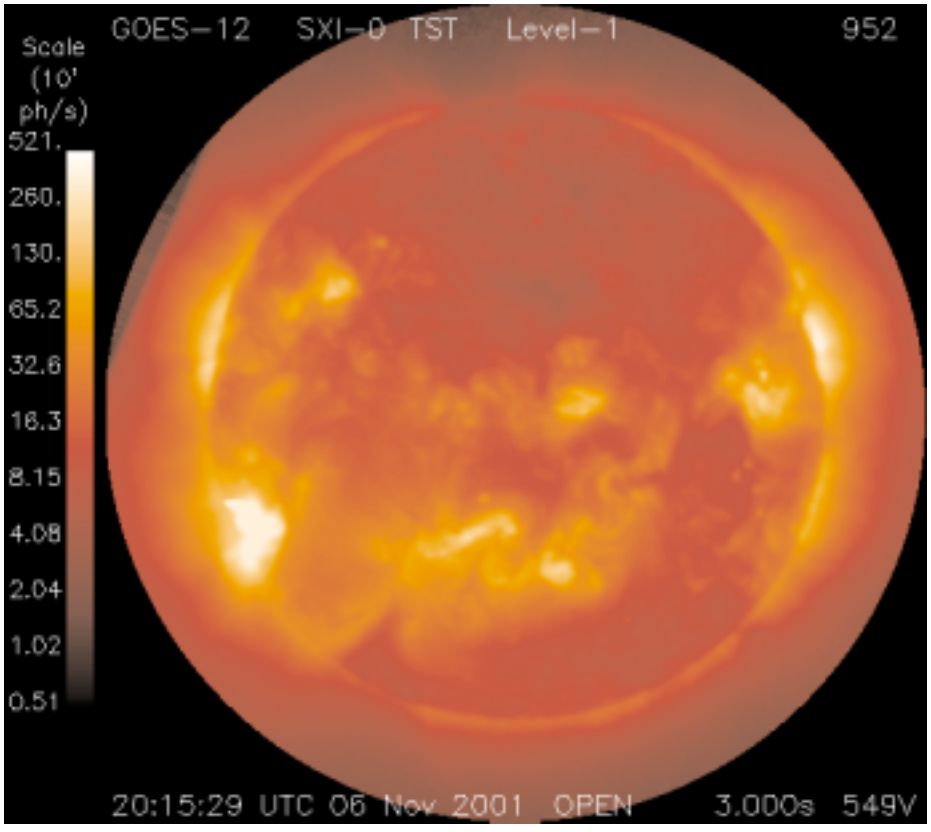

Figure 3-DOD-4. SXI imagery (visualization courtesy of NOAA).

AFW is taking steps to standardize space weather operations, improve space weather training for both providers and users, integrate dissemination channels for both space and terrestrial weather, and improve customer interaction. To improve interaction, AFW in conjunction with the Air Force Flight Standards Agency has modified the flight weather briefing form to include space weather effects on navigation and communication and establishing a space weather "pilot report" process to obtain feedback to identify, quantify, and archive space weather impacts.

RESEARCH INITIATIVES

The overarching objective of the Air Force meteorological and space environmental research and development (R&D) program is to provide system designers, operational weather personnel, and weather information users with the technology and tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan and in the Mission Area Plans of the Air Force major commands. Space environment R&D is targeted to meet the DOD's space weather requirements as summarized in the National Security Space Architect's Space Weather Architecture Study and the associated Transition Plan as well as the National Space Weather Program Implementation Plan, Second Edition. AFW also strives toward improvements in environmental operations through Cooperative Research and Development Agreements with for-profit companies.

In meteorological R&D, the Air Force is improving cloud depiction and forecasting (CDF) techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques. The Air Force has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. In addition to internal efforts, AFW will continue to rely on collaboration and leveraging of efforts with other federal meteorological agencies, research labs, and universities to further improve CDF system performance and meet other research needs.

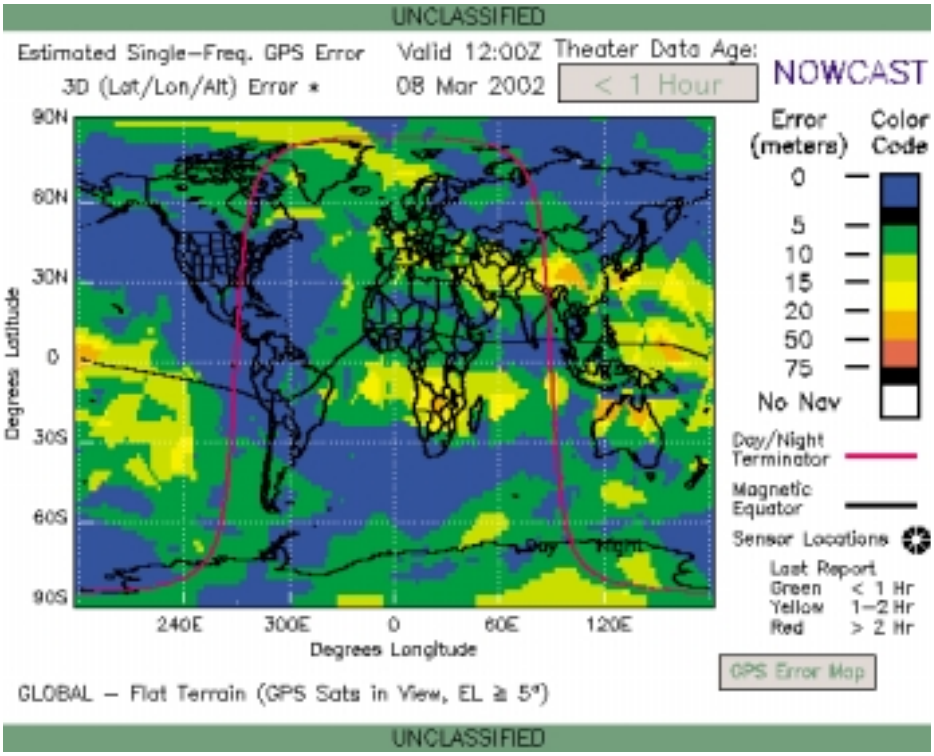

Figure 3-DOD-4. Single-Frequency GPS Receiver Error Map (visualized by HQ AFWA)

Mesoscale Modeling for Air Force and Army Operations. Efforts have continued for combining the MM5 and Land Surface Model (LSM) for use by Air Force and Army operations worldwide. Recent research paid off with the development of a coupled MM5-Land Surface Model (LSM) capability. The LSM analyzes the current state of the land surface to provide information to both DOD and civilian agencies and, through coupling with MM5, will improve forecasting performance in the low levels of the atmosphere. This allows AFW to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces. The advances achieved in the LSM are also being carried over into Weather Research and Forecast (WRF) model development, another area of HQ AFWA participation in research. HQ AFWA is closely collaborating with the National Center for Atmospheric Research (NCAR), the NCEP, the Forecast Systems Laboratory (FSL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others in WRF development. WRF is the next generation community model expected to replace MM5, and HQ AFWA is benefiting by leveraging the efforts of 537 registered users developing the model. HQ AFWA is preparing to fully implement WRF operationally in the 2004 to 2005 timeframe and in 2003 will continue with sponsorship and funding of development at NCAR and FSL, test and

evaluation of real-time runs of the WRF prototype, and will lead the LSM Working Group while participating in others.

Another example of how HQ AFWA has benefited from its R&D approach of strategic partnering is in the data assimilation arena. HQ AFWA's partnership with NCAR has resulted in an advanced 3-Dimensional VARiational (3D-VAR) data assimilation for the MM5 modeling system. The 3DVAR system will replace HQ AFWA's current Mesoscale Data Assimilation System and Multi-Variate Optimum Interpolation operational data assimilation system.

Atmospheric Optical Turbulence. Electro-optical (EO) systems are adversely affected by optical distortions caused by atmospheric thermal or refractive turbulence. As the sophistication of current and next generation military systems grows, the requirement for more detailed knowledge of fine scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such system whose performance is highly dependent on the variations of the meteorological conditions that produce turbulence. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide.

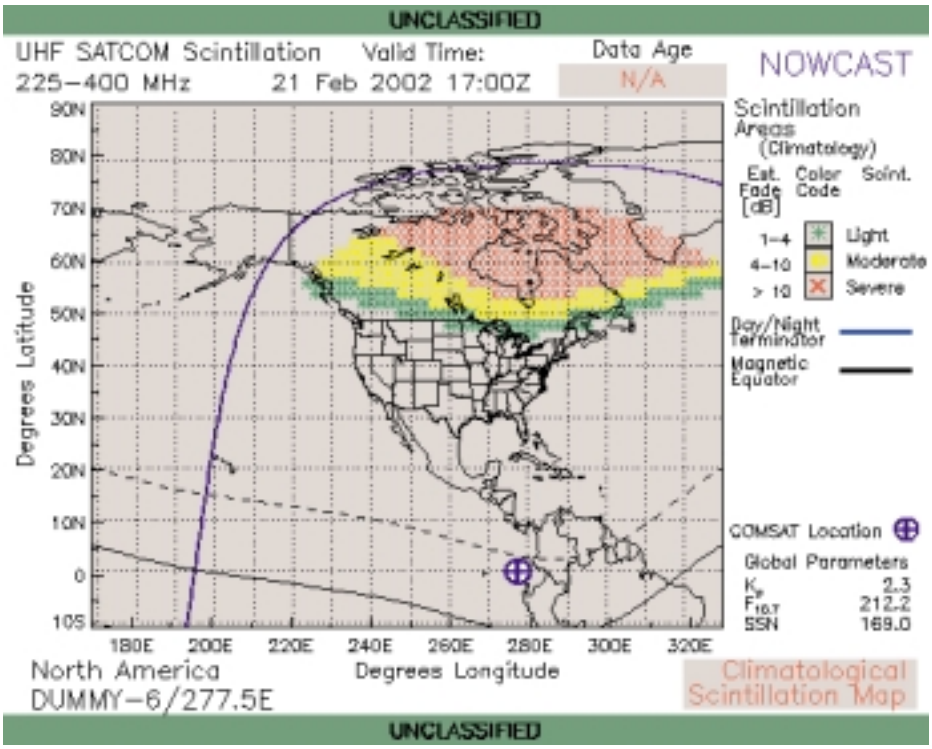

Figure 3-DOD-5. UHF Satellite Communications Scintillation Map (visualization by HQ AFWA)

Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge required by new EO systems.

Atmospheric Optical Opacity. Air- and Space-borne reconnaissance systems are adversely affected by optical distortions caused by clouds, fog, haze, and other airborne particles. As the sophistication of current and next generation military systems grows, the requirement for more detailed knowledge of smaller scale (meters) atmospheric behavior also grows. The Air Force's CDFS-II program seeks to address these needs.

Radar Analysis using Digital Terrain Elevation Data (DTED), MM5 data, and Advanced Propagation Model (APM) Prediction Software (RADMAPS). Through the University Partnering for Operational Support (UPOS) program, Johns Hopkins University Applied Physics Laboratory (JHUAPL) has developed RADMAPS, an application to assess and forecast anomalous propagation for ground based, airborne, and sea based radars. RADMAPS uses DTED from the National Imaging and Mapping Agency along with a newly developed and unique MM5 capability to forecast radar refractivity in the lower atmosphere and the APM (a model developed by Space and Naval Warfare Systems Command to predict atmospheric and terrain effects on radar performance).

United States Weather Research Program (USWRP). AFW first entered into discussions with USWRP in 2001 to explore expanded participation in the program and is looking forward to increased collaboration. USWRP's mission is to accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information. The program currently focuses on land falling hurricanes, heavy precipitation, and socio-economic impacts. AFW anticipates being able to leverage the advances made in the focus areas of landfalling hurricanes and heavy precipitation. AFW is eager to leverage future efforts in the areas of observing and assimilation strategies in data sparse regions

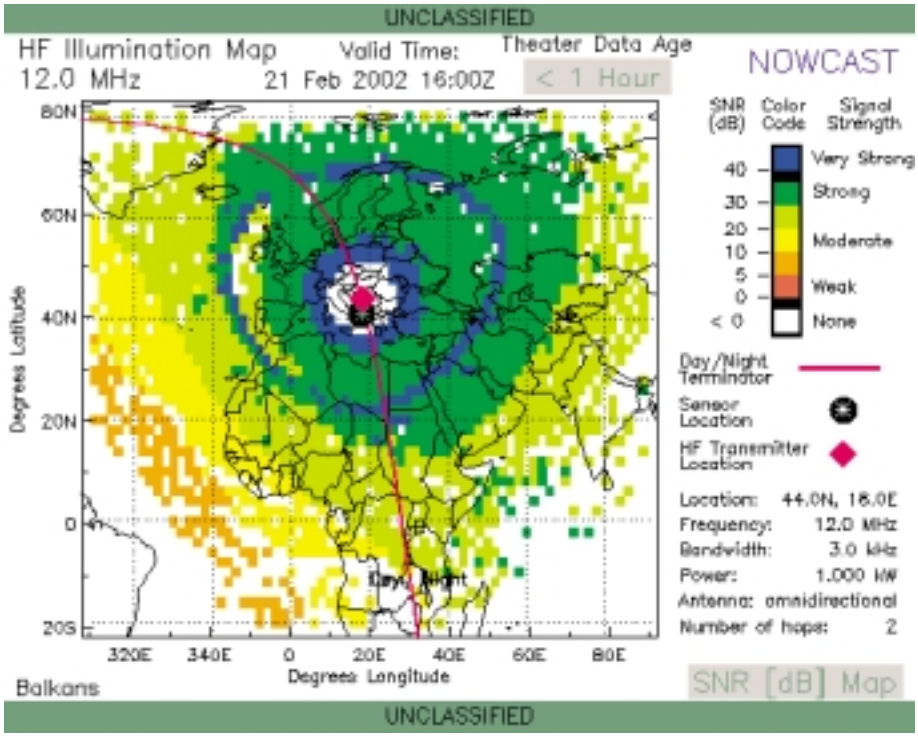

Figure 3-DOD-6. HF Illumination Map (visualized by HQ AFWA).

and urban forecast issues and opportunities. AFW is already committed to the USWRP-affiliated community development of the WRF model and will continue its involvement with this development during FY 2003. The basic WRF model is running at HQ AFWA now and initial results are very favorable.

University Partnering for Operational Support (UPOS). AFW continued to collaborate through the UPOS program with JHUAPL, the University of Alaska at Fairbanks Geophysical Institute, and the Army Research Laboratory (ARL). UPOS provides a link between university research and the DOD operational community and is currently focused on near-term forecasts of ground, tropospheric, ionospheric, magnetospheric, and solar weather. The goals of UPOS are to provide an alternate path for rapid transition of the best-applied research ideas to the warfighter and to raise awareness of DOD operational needs within the academic community. The partnership delivers prototype operational products to the Air Force and Army sponsors. The UPOS Steering Committee, which includes the Air Force Director of Weather, meets semiannually to review progress and approve new projects. UPOS includes warfighter exercise support to demonstrate utility of products through web-based, non-operational access as well as collecting direct user feedback for faster updates of the prototype systems. Some examples of tropospheric weather UPOS work include fine-scale polar numerical weather prediction, operational volcanic plume forecasting, and electromagnetic propagation forecast maps generated from MM5 output. Examples of space science work include high frequency radar and communication propagation to predict the area a transmitter can illuminate, forecasting coronal mass ejections, and improving determination of solar events that will cause militarily significant space weather effects on and near Earth.

Air Force Research Laboratory (AFRL). In other space weather research, AFRL programs focus on ionospheric impacts to radio frequency systems, space particle specification and forecast, solar disturbance prediction, and neutral density effects on Low Earth Orbit spacecraft. Working closely with the DMSP System Program Office at the Space and Missile Center under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include space environment sensors on the DMSP spacecraft, state-of-the-art ground-based scintillation detectors, total electron content sensors, DISS, the Improved Solar Observing Optical Network, and the Operationalized Space Environment Network Display suite of web-based products. AFRL also conducts customer-supported R&D for NPOESS, the DMSO, the National Reconnaissance Office, the Ballistic Missile Defense Office, the DOD High Performance Computing Modernization Office, and NASA. This program will continue in 2003 to build improvements for future operational implementation.

In addition to the AFRL research portfolio, AFW collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center, the Constellation Observing System for Meteorology, Ionosphere, and Climate, and the previously mentioned UPOS.

Community Coordinated Modeling Center (CCMC). AFW has been a full member of the consortium that formed the CCMC in 2000, co-chairing the CCMC Steering Committee, and contributing to center efforts since 2001 by providing Defense Research and Engineering Network connectivity and exclusive access to a set of supercomputing nodes at HQ AFWA. The CCMC mission is to provide a computing facility to enable, support, and perform research for the next generation of space weather models, preparing them for transition to operations

through the rapid prototyping centers at both the SEC and HQ AFWA. AFW provided funding for a CCMC replacement capability to be fielded in FY 2002. Additional information on the center is available at its web site at *http://ccmc.gsfc.nasa.gov/*.

Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). AFW, through the Air Force Office of Scientific Research, will continue to collaborate with the University Corporation for Atmospheric Research (UCAR), NOAA, NASA, the National Science Foundation (NSF), and the Navy on the COSMIC program. COSMIC comprises six micro-satellites planned for launch in 2005 to provide approximately 3,000 daily global observations of pressure, temperature, humidity, refractivity, ionospheric electron density, and ionospheric scintillation. The system will use GPS satellite occultation techniques to provide vertical atmospheric soundings as well as an ionospheric photometer and a tri-band beacon to measure electron densities and ionospheric parameters. The global coverage of atmospheric profiles should improve global-scale numerical weather prediction models and provide at least limited value in regional models and point analysis models. The space weather observations will complement other sensors to provide a more complete picture of the ionosphere and improve prediction of communication and navigation degradations. Additional information on COSMIC is available at *http://www.cosmic.ucar.edu*.

In conclusion, through a continuous process of review and definition, the Air Force documents its requirements for research aimed ultimately at providing timely, accurate, and relevant weather information to the warfighter today and in the future. In meteorological R&D, AFW is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation overall. Space weather research will continue with a strong program in 2003 both in AFRL as well as in leveraged programs such as UPOS to facilitate expediting needed capabilities to operations, at minimum expense.

PROGRAM OVERVIEW

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations. METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. The perspective is global, and historically focuses on areas outside of the contiguous 48 states, but the emphasis is on wherever the Fleet goes and includes force protection within the coastal waters of the United States. Developing METOC forecasts and determining potential effects on weapons system information requires:

- collection of data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic phenomena; and
- use of meteorological information in tactical decision aids and mission planning systems.

The Chief of Naval Operations, through the Oceanographer of the Navy (CNO (N096)), sponsors operational Navy METOC services and related research and development (R&D). The Navy METOC organization provides meteorological services for Navy and joint forces, meteorological products to the uniformed services and other Government agencies, and oceanographic support to all elements of DOD. The Oceanographer of the Navy sponsors programs in four closely related disciplines to provide worldwide, comprehensive, integrated weather and ocean support - meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment. Dual-hatted as the "Navigator of the Navy", the Oceanographer of the Navy serves as the Chief of Naval Operations' focal point for the development of technical standards for navigation plans, data standards, training, and navigation system certification. He also serves as an advocate and broker for all fleet navigation issues. The Oceanographer of the Navy streamlined his staff's organizational structure to better respond to fleet needs with two proactive divisions. The Requirements and Liaison Division works with the Fleet to establish METOC Requirements and maintains an active "Outreach" Program, both within and outside DOD. They work in conjunction with the Programming and Assessment Division who manages the R&D, materiel and infrastructure resources. The Oceanographer of the Navy's websites for information are at *www.oceanographer.navy.mil* and (for navigation information) *www.navigator.navy.mil*.

Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy. To ensure that all research and development supported by the Oceanographer is in direct support of the Naval mission as established by formal Navy doctrine, the Oceanographer recently developed and implemented a comprehensive framework to transition research to operations. The Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARSYSCOM) are the primary activities that manage naval research and transition to operations, and are supplemented by various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-155) is Navy's single program manager for METOC system development and acquisition.

Figure 3-DOD-7. USS MITSCHER (DDG-57) conducts underway replenishment in heavy seas.

METEOROLOGICAL SERVICES
UNITED STATES NAVY

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCCOM). Navy METOC activities are involved in worldwide collection of observations ashore, afloat and through remote sensors, and in the assimilation and processing of these observations on a global basis to support analysis and forecasting throughout the world.

The Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN), in Monterey, California, provides global, regional, and tactical observations, analyses, and coupled air-ocean forecasts. Environmental data is acquired through links with DOD and NOAA conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCCEN is the primary DOD global numerical weather prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory's Marine Meteorology Division, also in Monterey. NOGAPS provides global atmospheric predictions and drives a variety of ocean models, including the global Wave Watch III ocean wave model run at F L E N U M M E T O C C E N (Figure 3-DOD-8).

In near-shore regions, the small-scale interactions between the atmosphere, underlying ocean, and nearby land make it necessary to analyze and predict the battlespace environment with higher resolution and improved physics. In addition to the global product suite, FLENUMMETOCCEN is uniquely capable of providing high-resolution coupled air-ocean products on short notice for any location in support of global contingency military and humanitarian operations. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is an operational tactical system featuring data quality control algorithms; nested, non-hydrostatic physics; explicit moisture physics; aerosols; and improved data assimilation. Using lateral boundary conditions provided by NOGAPS, COAMPS provides a high-resolution, re-locatable, meteorological and oceanographic prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Western Pacific, Central America, Western Atlantic, the continental United States, and the Eastern Pacific. COAMPS is frequently run in other areas around the world as requirements dictate.

Figure 3-DOD-8. Landing Carft Air Cushion (LCAC) transports light armored vehicles.

NOGAPS and COAMPS forecast products are distributed via various communications systems including the Internet, either directly to Fleet customers, or through the Navy regional METOC centers. The regional METOC centers develop value-added products and services tailored to specific operational requirements. COMNAVMETOCCOM recently installed computer systems at all their regional centers to run COAMPS in theater, allowing them to respond to Fleet commanders' requirements in near real-time. As a complement to numerical forecast products, FLENUMMETOCCEN provides atmospheric and oceanographic observations, satellite products, data extracts, and data for tactical decision aids. Additionally, FLENUMMETOCCEN is the designated National "Core Processing Center" for remotely sensed microwave products under the Air Force/Navy/NOAA Shared Satellite Processing Agreement. The FLENUMMETOCCEN web site for information is *www.fnmoc.navy.mil*.

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, which is the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO recently began disseminating products from the world's first

operational global layered ocean model - NLOM. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is the National "Core Processing Center" for satellite-derived sea-surface temperature measurements, providing the global sea surface temperature data critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO is a DOD Major Shared Resource Center, enabling creation of the latest research and development models on the most modern scaleable, supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site for information is *www.navoceano.navy.mil*.

Tailored Theater and Regional Support

Theater and regional support are provided to forces ashore and afloat through six regional centers delivering METOC services within their broad areas of responsibility (AORs). Aligned with specific Naval Component Commanders of the Unified Combatant Commanders, these centers tailor services to theater requirements, and manage and prioritize dissemination of numerical products from FLENUMMETOCCEN and NAVOCEANO. Special products needed to meet requirements of Joint Force Commanders are also generated by the regional centers. Additionally, the Joint Typhoon Warning Center (JTWC) (operated by Navy and Air Force) is co-located with the Naval Pacific Meteorology and Oceanography Center in Pearl Harbor, Hawaii. Specific METOC products common to the regional centers include high winds and seas warnings for the world's oceans, tailored forecast support for Navy, United States Coast Guard (USCG), and NOAA ships at sea, and ship routing services for ocean transits (Figure 3-DOD-9).

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy (through NAVICECEN), NOAA, and the Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civilian and military activities.

Local and Aviation Support

NAVMETOCCOM Facilities at Whidbey Island, Washington, Naples, Italy, and Jacksonville and Pensacola, Florida, provide aviation forecast services as well as Fleet Operating Area (OPAREA) and local forecasts and warnings for aircraft, ships, submarines and naval bases and staffs. Additionally, there are 29 NAVMETOCCOM detachments worldwide. Though the detachments are primarily situated at Naval Air Stations for aviation safety of flight forecasting, several are located at Naval Stations in support of sea-going units. The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments and Facilities within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's National Centers for Environmental Prediction (NCEP). Overseas Detachments and Facilities use FLENUMMETOCCEN numerical weather products, in addition to USAF and foreign products. Additionally, FLENUMMETOCCEN provides aircraft routing services for military (primarily Navy) aircraft on demand.

One detachment, the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as part of the Federal Climate Complex.

On-Scene Support

The Navy's permanent afloat METOC assets are their OA Divisions, embarked aboard aircraft carriers, major amphibious ships and command ships. The OA division's primary objectives are safety of ships, aircraft and embarked personnel, optimum tactical and planning support to on-board warfare commanders, and tailored on-scene products and services for the assigned task force/group and Allied units in joint, combined, or coalition military and humanitarian operations (Figure 3-DOD-10).

Figure 3-DOD-9. Extreme pitch and roll conditions after storm passage cancel helicopter operations.

Deployable Mobile Environmental Teams (METs) are the primary source of on-scene Navy METOC support for other forces afloat and forces deployed ashore in remote operation areas. These teams provide short-term, on-scene services to DOD activities without organic METOC personnel, other government agencies, and elements of the armed forces of Allied nations during combined exercises or operations. METOC products and services provided by these METS are tailored to each unit's requirements, and include tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision-making, and climatological information for long-range planning.

Figure 3-DOD-10. AV-8 Harrier aircraft prepare to vertically take-off from sea.

UNITED STATES MARINE CORPS (USMC)

The mission of the Marine Corps METOC Service is to provide meteorological, oceanographic, and space environmental information, products, and services required to support Marine Corps operations and other military operations. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in an austere expeditionary environment. It is capable of providing sustained, comprehensive, and relevant METOC support to all elements of a Marine Air Ground Task Force (MAGTF), as well as bases and stations of the supporting establishment.

Organization

The Deputy Commandant for Aviation, Headquarters, United States Marine Corps (Code ASL-37) is the cognizant office for Marine Corps METOC support and requirements. The Marine Corps METOC organization consists of two operational chains-of-command, one for supporting establishment METOC units and the other for the Fleet Marine Force (FMF).

Supporting establishment METOC units are located worldwide at Marine Corp Air Stations (MCAS) and Facilities (MCAF). These activities are manned and equipped to provide direct aviation METOC support and services to host and tenant units at nine major air stations in the continental United States, one in Hawaii, and two in Japan (Figure 3-DOD-11).

Within the FMF, Marines typically deploy and employ as scalable, tailorable, combined-arms teams known as Marine Air Ground Task Forces (MAGTF). There are three sizes of MAGTFs. From smallest to largest, they are: Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB), and Marine Expeditionary Force (MEF). Additionally, Special Purpose MAGTFs (SPMAGTFs) may be formed to support operationally unique situations and/or requirements. All MAGTFs, regardless of size, share four organizational elements that vary in size and composition according to the mission: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

FMF METOC activities are organized, trained, and equipped to provide tailored support, products, and services to all combat elements of the MAGTF. METOC support is focused towards impacts on Expeditionary Maneuver Warfare (EMW) operations, particularly Operational Maneuver from the Sea (OMFTS). FMF METOC activities are fully interoperable within joint force operations as part of a service or functional component command. When directed to stand-up as part of a Joint Task Force Headquarters (JTF HQ), they are capable of planning, coordinating, and leading joint METOC operations. Marine METOC forces can rapidly transition from pre-crisis state to full operational capability in a distant theater to provide on-scene support to MAGTF, combined, joint, allied, and coalition operations and other military operations as may be directed.

FMF METOC assets are permanently assigned to Marine Expeditionary Force Headquarters (MEF HQ), Intelligence Battalions, Marine Wing Support Groups (MWSGs), and Marine Wing Support Squadrons (MWSSs). There are three Marine Expeditionary Forces strategically positioned for global response. I MEF, based in southern California and III MEF, forward based in Okinawa, mainland Japan, and Hawaii fall under the control of the Commander, Marine Forces Pacific. II MEF, located at bases in North and South Carolina, falls under the command of the Commander, Marine Forces Atlantic. MEF METOC personnel serve as special staff to the Commanding General (CG) and are under the direction and cognizance of the G-2 (Intelligence) Division.

The three Intelligence Battalions in the Marine Corps are co-located with respective Marine Expeditionary Force Headquarters. These battalions directly support the MEF G-2 and serve as MAGTF intelligence centers during operations. METOC is a vital part of the intelligence estimate and is an essential element that supports the Marine Corps Planning Process.

METOC personnel assigned to these commands provide expertise, products, and services that directly support the Intelligence Preparation of the Battlespace (IPB) process by helping intelligence analysts to effectively evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

Marine Aircraft Wings (MAWs) conduct the complete range of air operations in support of the MEF, to include anti-air warfare, offensive air support, assault support, aerial reconnaissance, electronic warfare, and control of aircraft and missiles. The MAW serves as the principle headquarters for the ACE and is co-located with each MEF HQ. Most of the MAGTF's METOC support assets reside within the MAW, specifically at the MWSG and its subordinate MWSSs. These assets are organized, structured, and capable of supporting a variety of MAGTF and ACE-specific operations as defined by the size, scope, and mission requirements. Dedicated METOC support is available for all MAGTF elements from within the MAW/ACE.

METOC Support Capabilities

Meteorological Mobile Facility (MetMF). The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF. The MetMF provides a METOC support capability similar to that found in garrison METOC facilities, is normally deployed as part of an entire MWSS to a Forward Operating Base (FOB), and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach a small METOC team with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate service personnel augmentation, the MetMF is also capable of serving as host for an in-theater Joint METOC Forecasting Unit (JMFU) during joint operations and exercises.

MEF (Weather) Support Team (MST). MSTs are task organized and equipped to provide a limited level of METOC support to combat elements other than the ACE (e.g. CE, GCE, and CSSE) and can be assigned to support MEU operations. It is capable of rapidly deploying as part of a first-in level of METOC support response to a crisis and can be easily integrated into an Air Contingency MAGTF (ACM). Additionally, the MST can be assigned to augment a JMFU during joint operations (Figure 3-DOD-12)

Figure 3-DOD-11. MEF Support Team (MST) developing a forecast using portable equipment.

One MWSS within each MAW is structured and organized to provide up to four fully manned MSTs that would each consist of one METOC officer, two forecasters, and two observers. When deployed, the MST will normally be assigned to the G/S-2 (Intelligence) division/section of the supported combat element or MEU. The MST does not have a standalone METOC capability. Instead, during operations they collect METOC products, data, and information from the nearest deployed MetMF, Navy METOC OA Division afloat, host nation or other METOC support organizations and agencies to satisfy METOC information requirements.

Specialized METOC Support

The Marine Corps' Chemical Biological Incident Response Force (CBIRF) was established in 1996 as a result of Presidential Decision Directive (PDD) 39 to manage the consequences of Nuclear, Biological, and Chemical (NBC) materials or weapons used by terrorists. This national level asset is part of the re-activated 4th Marine Expeditionary Brigade - Anti-Terrorism (MEB-AT) located at Indian Head, Maryland. It is comprised of specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed and/or respond to a credible threat of a Chemical, Biological, Radiological, Nuclear, or High Yield Explosive (CBRNE) incident in order to assist local, state, or federal agencies and designated Combatant

Commanders in the conduct of consequence management operations. Within the S-2 (Intelligence) section, a permanently assigned METOC forecaster provides specialized NBC dispersion forecast products and services that aid mission accomplishment of this organization.

METOC Support Doctrine

Marine Corps Warfighting Publication (MCWP) 3-35.7, MAGTF Meteorological and Oceanographic Support, provides more detailed information about the Marine Corps METOC Service. An electronic copy is available for viewing and downloading from the Marine Corps Combat Development Command (MCCDC), Doctrine Division web site at *ismo-www1.quantico.usmc.mil/docdiv*.

MAJOR METOC SYSTEMS

The capability to provide near real-time global, regional, and local METOC services to the Navy and Marine Corps team requires a robust and evolving set of leading edge technology tools. Theses tools are embodied in the following systems:

Primary Oceanographic Prediction System (POPS) II Upgrade (POPS II U) operates complex computer-based models of the world's ocean and atmosphere and disseminates METOC forecasts, charts, imagery and operational data sets to support deployed Navy and DOD forces worldwide. This data is essential to the safety and effectiveness of the Navy's operational platforms, sensors, and weapons including cruise and ballistic missiles, ships, aircraft, radar and sonar. POPS II U prediction models must provide horizontal resolutions of 1-5 kilometers and in near real-time for use in on-scene tactical decision aids and systems.

POPS II U is the DOD approved system that operates global, regional, and tactical atmospheric, oceanographic, ice, wave, and tropical cyclone models. The POPS II U, located at FLENUMMETOCCEN also provides the computing capability required to support DOD's only global atmospheric forecast model pursuant to an agreement between the Navy and Air Force. Under an umbrella memorandum of agreement signed in 1993 between NOAA and FLENUMMETOCCEN, both sides provide cooperative efforts in operational numerical modeling, data exchange, and mutual backup between NCEP and FLENUMMETOCCEN. In 1999, FLENUMMETOCCEN provided numerical modeling backup capability for NOAA's Tropical Prediction Center and NWS forecast office use during several NCEP supercomputer outages including a five month period following the NCEP computer fire outage in September.

POPS II U is composed of a number of different high-performance computer systems, including two SGI Origin 3800s (one with 512 processors, the other with 128 processors). These state-of-the-art computer systems form the basis of METOC support throughout DOD. This capability includes state-of-the-art decoders, data managers, quality control algorithms, and observational assimilating software for all types of METOC data from all available sensors. These data will support state-of-the-art numerical weather, ocean, chemical/biological, and acoustic models, running in multiple nested fashion from global scale models at resolutions of tens of kilometers to battlegroup/battlefield models at resolutions of a few kilometers.

The POPS II U System performance improvement objectives optimize DOD support in the following specific areas:

- METOC forecasting skill worldwide for longer time periods
- Aircraft routing services
- Safe and direct ship routing services
- Hurricane, cyclone, and tropical storm prediction worldwide
- Open ocean and coastal wave prediction
- Precipitation prediction
- Refractivity conditions/ducting range
- Acoustics support
- Ballistic missile targeting support
- Search and rescue
- Chemical/biological/nuclear transport prediction

Distributed Atmospheric Modeling Prediction System (DAMPS). For centuries, military commanders have looked to the weather for tactical advantage. The Navy is currently the nation's only military service that operates a distributed model in support of tactical weather prediction. DAMPS allows users to ingest high-resolution data and on-scene observations into regional and global model information received from the Fleet Numerical Meteorology and Oceanography Center in Monterey, California. The result is an on-scene weather model that provides accurate weather predictions for an operating area within a 24-hour timeframe.

DAMPS is fielded at all Navy METOC centers worldwide and uses the COAMPS model to develop METOC prediction products out to 48 hours. DAMPS uses real-time weather data from ship and battle group observations, including parameters such as wind, temperature, cloud, visibility and radar data, and then incorporates this data into its analysis. This analysis can be highly focused on any area of interest.

Tactical Environmental Support System (TESS). The Navy is presently undergoing migration towards a modular, interoperable suite of systems to ingest, process, fuse, display, and disseminate METOC data. The program consists of five seamless versions known as the Naval Integrated Tactical Environmental Subsystem (NITES) versions I-V. NITES systems will be fielded in FY 2000 through FY 2004. The five NITES versions are:

- NITES I. Provides Navy decision-makers on major combatant ships with METOC assessments and forecasts, and integrates data with sensor and weapon platform parameters for system performance assessments. Theater METOC Centers use NITES I to provide value-added products to fleet units, and the numerical prediction guidance generated by FLENUMMETOCCEN.
- NITES II. Makes METOC data and products available to Navy and Marine Corps activities afloat and ashore via the Global Command and Control System-Maritime (GCCS-M). TESS data and products are used to feed tactical decision aids resident within GCCS-M. NITES II is the basis for the Joint METOC Segment of the new Global Command and Control System (GCCS) V3.0.
- NITES III. An unclassified forecast, briefing, and display system tailored to Naval METOC shore activities in support of aviation operations.
- NITES IV. A portable system tailored to Mobile Environmental Team (MET) and USMC Meteorological Support Team (MST) METOC requirements. Fielding of NITES IV is expected to commence in FY 2003.
- NITES V. A forecast, briefing, and display system for foreign military sales to ensure interoperability with our allies. It is a follow-on to the Allied Environmental Support System (AESS) and will incorporate capabilities used in the other NITES variants.

Tactical Environmental Data Server (TEDS). TEDS is a storage and data management system for meteorological and oceanographic information. It is the central engine in both the Tactical Environmental Support System (TESS) and the Navy Integrated Tactical Environmental System (NITES), providing the broadest support via access to the full spectrum of client applications and METOC models. TEDS architecture connects to government historical databases and commercial relational databases management systems using network and Internet protocols. With the associated METCAST automated delivery software, users with Internet access can monitor information updates on demand, continuously, or on schedule.

Meteorological Data Receiver-Recorder (AN/SMQ-11 and AN/FMQ-17). These systems are the principal Navy systems to acquire environmental data directly from satellites. There are different equipment configurations for ships (AN/SMQ-11) and shore sites (AN/FMQ-17), and through their interface with TESS variants they provide remotely sensed information to the operator.

Automated Surface Observing System (ASOS). ASOS supports aviation and local area observing requirements at Navy and Marine Corps stations worldwide, leveraging development efforts of the National Weather Service (NWS). ASOS helps assimilate field meteorological parameters and facilitates efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN). NAVMETOCCOM is certifying ASOS units at local and remote USN/USMC airfields for stand-alone use during off-duty hours, when observers are not present to verify the official station observation. NMOC expects to complete major airfield certification by mid-FY 2002, and certify the remainder of remotely located sites by the second quarter of FY 2003.

Supplemental Weather Radars (SWR) (AN/FPS-131 and AN/TPS-76). The Navy has procured Supplemental Weather Radars to provide Doppler weather radar coverage at selected Navy and USMC sites, mostly overseas, outside of NEXRAD coverage. This system replaced the obsolete AN/FPS-106 non-Doppler weather radars.

Meteorological Mobile Facility Replacement (MetMF(R)). The MetMF(R) is a transportable system that houses meteorological support equipment for the Marine Air Ground Task Force (MAGTF). This 8 x 8 x 20 foot van provides a fully functioning weather office designed to support Marine Corps expeditionary airfield operations for 30 days without resupply. It includes sub-systems for data collection (local, remote and upper air sensors), data processing, satellite data ingest and display, Doppler radar, communications, briefing support, and support for remote forces. The MetMF(R) is interoperable with the Marine Corps C^4I systems and METOC systems of the other Services via the Global Command and Control System (GCCS).

Figure 3-DOD-12. USMC Meteorological Mobile Facility (MetMF) deployed in support of winter.

Operational Products and Services

Optimum Track Ship Routing (OTSR), and Optimum Path Aircraft Routing System (OPARS) are advisory services for fleet units. They are based on NOGAPS, COAMPS and wave forecast data, are tailored to the customer, and provide guidance to the forecaster for the safe operation and cost-effective routing of DOD ships and aircraft, just as they have for nearly 30 years. OTSR and OPARS save the operating forces of all services approximately $57M/year in reduced fuel consumption and personnel costs.

The Navy Oceanographic Data Distribution System (NODDS) was discontinued in October 2001. The Navy METCAST system is a PC-based software package used to make FLENUMMETOCCEN numerical products available to front line DOD users. All standard meteorological and oceanographic fields, synoptic observations and basic DMSP satellite imagery are also available.

The Joint METOC Viewer (JMV) is a more recent capability that is integrated into NITES and has gradually replaced NODDS. Building on the availability of the Internet and the successful user interface of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. Authorized DOD and government users with Internet access now have a simple, cost-efficient way to display weather and ocean information on various computer platforms and operating systems. JMV is operational at several hundred DOD and other government sites including ships, and is available to authorized non-government users as well.

WxMAP ("Weather Map") is a Web-based service from FNMOC that allows military and civilian users worldwide to access numerical output of selected weather parameters at pre-established geographical areas throughout the world. Because of continually emerging Internet technology, a large subset of these products can also be made available to the general public at no additional cost. WxMAP is being replaced by the more robust "MyWxmap" in 2002, and will eventually be integrated into various Web portals now under development.

Since 1983, the Naval Regional Meteorology and Oceanography Center, in Norfolk, Virginia, has provided long-range forecasts in support of Energy Conservation efforts at Naval shore installations in the continental United States. The services are primarily in the form of extended-range (10 day) temperature forecasts provided to energy managers to assist in optimizing power plant operations. Monthly temperature/degree day outlooks and long-lead (12 month) seasonal and precipitation forecasts are also issued to assist in strategic planning of fuel purchasing and resource allocation. Documented savings from the Energy Conservation Forecast Program exceed $62M, with the majority of savings resulting from power plant steam/air conditioning on/off recommendations and energy resource/fuel allocation based on long-lead forecast products. Customers include 128 Navy and Marine Corps facilities and commands.

SUPPORTING RESEARCH

The Navy administers a diverse research and development (R&D) program, ranging from software development to sensor engineering, and processing, display, and distribution devices. Application of R&D activities of other Services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is emphasized.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into operational meteorological and oceanographic models is key to a successful numerical prediction program. This ongoing process includes work at universities and the Naval Research Laboratory's Marine Meteorological Division to keep the NOGAPS and COAMPS at the leading edge of technology. Development is also underway to improve data assimilation, quality control, and management techniques to support these models. A major numerical weather prediction thrust is underway to develop a shipboard tactical atmospheric forecast capability to assimilate locally acquired data in real-time and deliver high resolution (5 km), limited area (100s of km), short range (12-24 hr) atmospheric predictions in tactical timeframes. The Navy's suite of models also includes phenomena such as waves, tides, ice, tropical cyclone, and biological/aerosol transport. A complete set of numerical modeling "Roadmaps" can be found at *www.cnmoc.navy.mil*.

The Navy R&D program in remote sensing develops techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are exploited to the greatest extent possible and plans are in place to incorporate new capabilities when introduced. Because many satellite-processing algorithms are designed for use with tactical systems, expert or rule-based processes are used where possible to reduce human-intensive interpretation.

ONR and SPAWARSYSCOM continue to explore techniques for assimilating environmental data through non-traditional sensors. One such effort is investigating the AEGIS Weapon System's AN/SPY-1 radar and developing the ability to produce NEXRAD-like radar information from ships at sea.

INTERAGENCY COOPERATION

Navy and Air Force have long been cooperating in DOD weather support,

and these efforts have led to such successes as the Defense Meteorological Satellite Program and the Joint Typhoon Warning Center. Recently, the two services have reinvigorated efforts to increase efficiencies in their METOC programs through greater cooperation, particularly in the area of support to military Command & Control and Intelligence/reconnaissance systems. The most recent initiative under NAVAF-21 (Navy/Air Force Cooperation in the 21st Century) was the creation of the Joint METOC Interoperability Board (JMIB). As examples, working groups of this board have been developing a road map to build a Four Dimensional Data Cube, accelerating the development of common data base segments and API's, and developing a common mapping tool kit. All of these efforts are designed to ensure consistent, accurate, relevant, and timely information for both automated and human-in-the-loop planning and decision systems.

To maximize efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) between these two agencies was signed in 1993. Additionally, an agreement for shared processing of remotely sensed data was last updated in 1997. Both agencies continue to identify new areas of potential cooperation and review existing agreements for conversion into annexes to this MOA. Specific areas include:

- Cooperative efforts in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCCEN and the National Centers for Environmental Prediction (NCEP).
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- Cooperative efforts between FLENUMMETOCCEN and the Pacific Fisheries Environmental Lab of the National Marine Fisheries Service.
- Air Force Weather Agency (AFWA)/Navy (FLENUMMETOCCEN, NAVOCEANO)/ NOAA-NESDIS agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.
- Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).

MOAs also exist between the DOD, DOC, and DOT concerning procurement and operation of NEXRAD. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

There are numerous other bilateral agreements involving FLENUMMETOCCEN, NAVOCEANO and the Navy Regional Centers with other DOD activities. These agreements range from weapons of mass destruction hazard dispersion modeling to specific backup capabilities.

NATURAL DISASTER MITIGATION

Navy METOC plays a vital role in reducing the impact of natural disasters to units both ashore and afloat. Severe weather warnings are issued at Naval facilities by the local NAVMETOCCOM activity when conditions warrant. For ships operating at sea without METOC personnel embarked, tailored enroute weather forecast messages (WEAX) and high winds and seas warnings provide commanding officers with advance notice of heavy weather, and OTSR forecasters monitor ship movements and provide heavy weather avoidance recommendations.

Tropical cyclones and even severe winter storms provide even greater challenges, as ships cannot generally "ride out" storms in port without sustaining damage. Similarly, once they get underway (or "sortie") ships must steer well clear of the highest winds and seas, to avoid personnel injuries and damage and ensure their stability limits are not exceeded. Storms of little consequence to the general public - those that remain well out at sea - are still of great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3 to 5 days in advance of potentially dangerous weather. Sortie decisions are extraordinarily difficult to make because of their high cost and impact on personnel and operations. In making these decisions, Fleet commanders must strike a balance between the risk of staying inport versus the cost and potential for damage at sea. Additionally, naval exercises and ship transits are often placed at risk by multiple tropical cyclone events, which can make successful evasion extremely difficult.

Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS and adjacent ocean areas, tropical cyclone forecasts in particular are closely coordinated with those of the NWS. Overseas, local tropical cyclone warnings and forecasts are based on guidance provided by the Joint Typhoon Warning Center (JTWC), Pearl Harbor, Hawaii. FLENUMMETOCCEN has been designated as the alternate JTWC by the United States Combatant Commander, Pacific.

ARMY TRANSFORMATION

Global changes to the strategic environment dictate that the Army significantly alters the way it conducts business. On 12 October 1999, the Secretary of the Army and the Chief of Staff of the Army articulated a vision designed to posture the Army so that it can better meet the demands of the 21st Century: "Soldiers on Point for the Nation…Persuasive in Peace, Invincible in War." This requirement to transform the Army is based upon emerging security challenges in the 21st Century as well as the requirement to respond more rapidly across the full spectrum of operations. In support of the National Security Strategy (NSS), the strategic significance of land forces lies in their ability to not only fight and win our nation's wars but also to provide options that shape the global environment to the future benefit of the United States and its allies. To this end, the Army developed a strategy and plan to guide this transformation (Figure 3-DOD-13).

Figure 3-DOD-13. The Strategic Environment.

The Army Vision is about People, Readiness and Transformation. People are the centerpiece of our formations; leadership is our stock in trade. It is imperative that we continue to take care of our quality soldiers, civilians, veterans and their families as we transform our Army. Readiness remains, as it has always been, our top priority. We have a non-negotiable contract with the American people - to fight and win the nations wars. We must ensure that at all times, the Army can meet demands of the National Military Strategy (NMS) and requirements specified in the Joint Strategic Capabilities Plan (JSCP). Finally, the Army must transform to become more strategically responsive and dominant at every point on the spectrum of operations.

The vision represents goals for the Army while Transformation and its accompanying Transformation Campaign Plan (TCP) are vehicles for becoming more strategically responsive and dominant. Achieving this vision requires a complete and radical transformation of the entire Army.

Transformation consists of three major objectives: Initial Force, Interim Force and Objective Force, with three corresponding phases (Figure 3-DOD-14). The first phase of Army Transformation has already begun. During this phase, the Army is fielding an Initial Force of two Brigade Combat Teams at Ft. Lewis, Washington, that will establish and validate an organizational and operational model for Interim Brigade Combat Teams. To bridge the gap between the capabilities of today's force and the Objective Force, it is necessary to field an Interim Force of six brigades, employing Interim Armored Vehicles (IAVs) and currently available commercial off-the-shelf (COTS) equipment. These Interim Brigade Combat Teams (IBCTs) are the vanguard of the future Objective Force - they will have full spectrum capability and be available for apportionment to the warfighting CINCs. These Interim Brigades also will have the capability to deploy anywhere in the world in 96 hours. The Army envisions fielding the first units of the Objective Force in eight years or less. This force will not only retain the capability to deploy a combat-capable brigade anywhere in the world in 96 hours but also a division in 120 hours and five divisions in 30 days. The Objective Force will provide our national leaders with an increased number of options for regional engagement, crisis response and sustained land force operations. The Objective Force is designed and built around a Future Combat System (FCS) that will incorporate state of the art technologies and capabilities into a multi-mission combat system. The Army has significantly increased spending in science and technology in order to develop the operational capabilities of the FCS and the overall force. Throughout the Transformation, readiness remains our top priority - the Legacy Force provides this capability. The Army must fulfill its non-negotiable contract with the American people-to fight and win the Nation's wars. Therefore, the Army must sustain and recapitalize its Legacy Force to guar-

antee maintenance of critical warfighting readiness. To accomplish this, the Army will recapitalize selected legacy formations in its Active and Reserve Components to enhance key armored and aviation systems as well as enhance light force lethality and survivability.

These changes to the Army structure dictate changes in both weather support requirements and the way weather is provided to the new Brigade Combat Teams. Weather teams will be smaller in size and will depend more heavily on "reach back" capabilities to obtain meteorological data. The Air Force is working with the Army to optimize the type and level of weather support that will be provided to the new brigades, while still maintaining appropriate support to the legacy force during transformation.

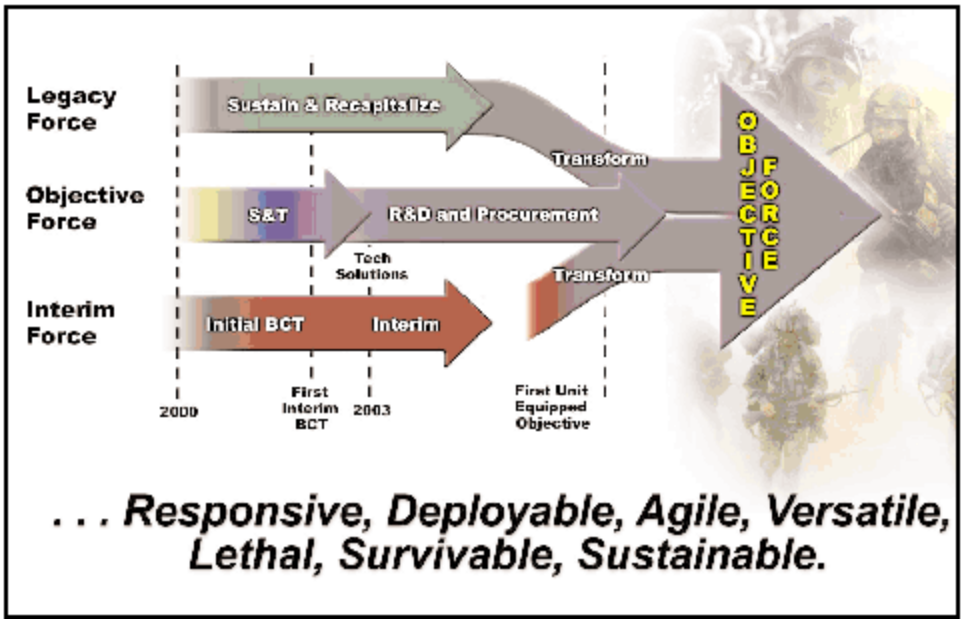

Figure 3-DOD-14. United States Army Transformation.

OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

United States Army weather support is a mix of Army and USAF personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/ Air Force Joint Instruction (AFJI) 15-157, Weather Support for the United States Army, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army providing weather support. The United States Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers (Figure 3-DOD-15). AF Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. United States Army Forces Command (FORSCOM), United States Army Europe (USAREUR), United States Army Pacific (USARPAC), United States Army Special Operations Command (USASOC), Eighth United States Army (EUSA), and United States Army Training and Doctrine Command (TRADOC) have AF Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) Crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime training and activation the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies the ANG may augment the active Army Combat Weather Teams (CWTs).

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is described under Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF CWTs for tactical operations. The Integrated Meteorological System (IMETS) is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence and Effects. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to Field Artillery meteorology programs.

ARTYMET Crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET Crews also take limited surface observations at tactical locations on an "as needed" basis to

support artillery operational requirements.

ARTYMET Crews in the Active Component (AC) and RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF CWTs, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The CECOM section provides a complete description of MMS. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. When directed by the Intelligence Officer (S2), Intelligence personnel in the forward combat areas take these observations.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff, G-2, is responsible for Army weather support policy. The Office of the Deputy Chief of Staff, G-3, is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office and an Intelligence Officer assigned to the Air Force Weather Agency at Offutt AFB Nebraska.

Army Operational Support provided by the Air Force

Under AR 115-10/AFJI 15-157, the AF is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison active component (AC)/RC support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather units. While direct support of the Field Artillery remains an Army responsibility and is supported by Army ARTYMET teams, AF CWTs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiments to provide direct, on site weather support. AF Operational Weather Squadrons and CWTs provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. The AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfield Weather Stations. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army Integrated Meteorological System (IMETS) is fielded for these purposes and is operated by AF CWTs. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to AF CWTs through an Army Table of Organizations and Equipment (TOE).

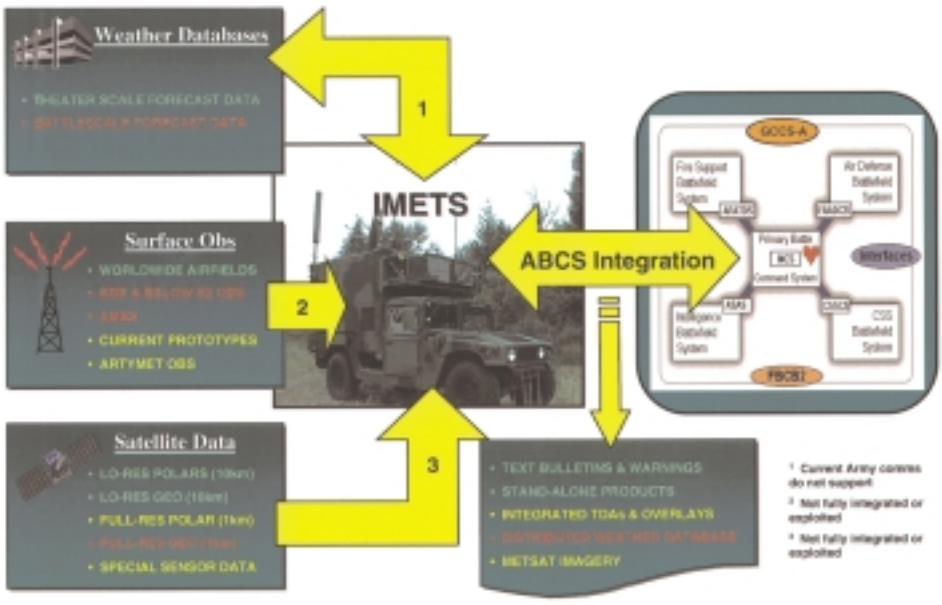

Figure 3-DOD-15. Army Weather Support Architecture.

Eighth United States Army Support

Eighth United States Army (EUSA) requires, and uses, Army resources to conduct two major meteorological services in direct support of Army operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observa-

tions to support all tactical units and operations.

Two artillery meteorological (ARTYMET) crews with the Second Infantry Division use AN/TMQ-41 Meteorological Measuring Sets to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect routine (usually daily) upper air observations for training; these observations are typically fed into the global weather database.

Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers (TOC) during contingencies or exercises and, in turn, are disseminated to and through United States Air Force (USAF) weather teams supporting Army air, ground, or special operations.

Army Operational Support Provided by USAF

USAF weather personnel assigned to the 607th Weather Squadron (607 WS) provide fixed and tactical weather support to EUSA units and installations. 607 WS provides garrison and tactical weather warning, observing, forecast, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations. 607 WS units provide direct, on-site support at eight EUSA installations and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. In FY 2000, the 607 WS reengineered weather support in theater and the 607 WS's Theater Forecast Unit (TFU) took over forecasting responsibilities for the eight EUSA locations. Theater forecast responsibility will move from the TFU to 20th Operational Weather Squadron at Yokota in FY 2002, though 607 WS will continue to occupy the same facilities at all eight locations. The EUSA Cadre Weather Teams are now primarily responsible for providing their customers with observations and tailored mission execution forecasts. 607 WS provided 101 trained weather personnel and required fixed and tactical weather sensing, data processing, and communications equipment in FY 2002. The number of trained weather personnel will drop to 78 after the move of theater forecast responsibility to 20th Operational Weather Squadron. EUSA provides supporting USAF units needed garrison and tactical communications, tactical vehicles, MTOE and CTA equipment, and operating funds (for expendables, maintenance, etc.) IAW AR 115-10/ AFJI 15-157.

United States Army In Europe And Seventh Army

United States Army Europe (USAREUR) and 7th Army require and use Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

7th Weather Squadron (7 WS) provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, SWO services, and specialized support. The United States Air Forces in Europe (USAFE) Operational Weather Squadron (OWS) at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units. CWTs located at V Corps and its aviation assets, 1st Infantry Division and its aviation brigade, 1st Armored Division and it aviation brigade, Southern European Task Force, and 7th Army Training Command, as well as 7 WS supporting 7th Army, evaluate and tailor these forecast products to produce mission execution forecasts.

The mission of 7 WS and its 9 detachments is to provide weather operations packages to conform to the Army's Transformation initiative. 7 WS will match the deploying weather force structure to the mission that USAREUR is called upon to execute. 7 WS will utilize "reachback" capabilities to the maximum extent possible to minimize the deployed footprint without compromising weather operations.

Weather units received a new tactical observing system, the TMQ-53. Its lightweight capability allows units to set it up and pack it up for movement in minimal time. It has become the replacement for the Portable Automated Surface Observing System (PASOS) in the Balkans.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving forecast graphics and alphanumeric data. Data is received via Very Small Aperture Terminal (VSAT) and hard-wire circuits. The New Tactical Forecast System (NTFS) is the primary equipment used for deployed locations with data received via Tactical VSAT, NIPRNET and SIPRNET. Units also use the NATO Automated Meteorological Information System (NAMIS) to receive NATO generated weather products. NAMIS software is hosted on a laptop and receives data via VSAT. Satellite imagery (METEOSAT and DMSP) is received via the Small Tactical Terminal (STT), a direct readout system (Figure 3-DOD-16). Seven Integrated Meteorological Systems (IMETS) have been fielded within USAREUR. The IMETS is geared to interface as a module of the Army Battlespace Control System to inject weather decision products into the common battle picture for Army commanders. A

Figure 3-DOD-16. An Air Force Combat Weather Team member sets up a Small Tactical Terminal during a USAREUR exercise (United States AF Photo).

lighter version of the IMETS (IMETS-L) is programmed for fielding beginning in FY 2003 with expected fielding in USAREUR in FY 2004. This version is designed to mirror the capabilities of the IMETS Vehicle mounted configuration currently fielded, but will be much more deployable.

USAREUR provides supporting USAF weather teams with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four artillery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking limited observations at forward areas in the battlespace.

United States Army Special Operations Command (USASOC)

Weather support to USASOC consists of forecasts and observations, climatological studies and course of action recommendations to aid commanders in improving efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited scope meteorological observations in direct support of Army operations using tactical weather kits to collect limited weather data in data sparse permissive and non-permissive environments. Observations are typically collected by Army Special Operations Forces at the team level and are passed to operating bases for use by Army commanders and staff, as well as Air Force Special Operations Command (AFSOC) and Air National Guard (ANG) weather personnel. AFSOC and ANG weather personnel supporting USASOC are assigned to the 10th Combat Weather Squadron (CWS), OL-A, 320 Special Tactics Squadron (STS), OL-A, 321 STS and the 107th, 146th, and 181st ANG Combat Weather Flights (CWF's). These weather units provide garrison and tactical support to USASOC units including the 75th Ranger Regiment and subordinate battalions, the 160th Special Operations Aviation Regiment, seven Special Forces Groups and subordinate battalions and 2 Psychological Operations Groups. Support provided includes climatological information, mission forecasts, command decision forecasts, aviation forecasts and observations, drop zone forecasts and observations, special reconnaissance, and Foreign Internal Defense/Unconventional Warfare. The 10 CWS also provides staff support to USASOC, the United States Army Special Forces Command (Airborne), and the United States Army John F. Kennedy Special Warfare Center and School.

United States Army Pacific (USARPAC)

United States Army Pacific (USARPAC) uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating surface weather observations to support tactical units and operations.

USARPAC provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds.

The Integrated Meteorological Systems (IMETS) and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS reachback for data via Army provided NIPRNET and SIPRNET conduits. Deployed weather teams also use the Small Tactical Terminal (STT) for direct reception of weather satellite imagery.

The 17th Operational Weather Squadron (OWS) provides USARPAC with garrison and tactical weather warnings, forecasts, special support, and SWO services during contingencies and humanitarian operations. Additional CWTs assigned to United States Army Japan (USARJ), United States Army Hawaii (USARHAW) - including the 25th ID - and United States Army Alaska (USARAK), including 172th SIB, provide direct, on-site support at 5 USARPAC installations. The CWTs also deploy with their customers providing tailored battlefield observations and forecasts.

Weather reengineering will reduce the requirement for forward deployed weather personnel, and instead leverage IMETS and other recently fielded technology for reachback capability. The 17th OWS will provide regional weather support, allowing the forward deployed forces to focus on specific area and target forecasts.

There are three subordinate commands within USARPAC: United States Army, Hawaii (USARHAW), United States Army, Alaska (USARAK), and United States Army, Japan (USARJ).

The 20th Operational Weather Squadron (20 OWS) at Yokota AB, Japan, provides operational-level forecast products for the USARJ AOR, to include all USARJ units. A member of the 20 OWS's staff serves as the USARJ's SWO. In addition, specific resource protection support (i.e. weather advisories, warnings, and watches) is provided for Camp Zama, Japan. An AF CWT assigned to the 374th Operational Support Squadron at Yokota AB is located at Camp Zama. It provides observational support and produces mission execution forecasts to support aviation operations.

The 11th Operational Weather Squadron (11 OWS) at Elmendorf AFB, Alaska, provides operational-level forecast products for the Alaskan Command AOR, to include all USARAK units. The Commander, 11th Operational Weather Squadron, serves as the CG, USARAK's Staff Weather Officer. Additionally, the 11 OWS is responsible for Terminal Aerodrome Forecasts for Fort Wainwright, along with resource protection weather support (i.e. weather advisories, warnings, and watches) for Forts Wainwright, Greely, and Richardson. The 11 OWS provides flight weather briefing support, as required, to Army, Army Reserve, and Army National Guard aviation assets in theater. An AF CWT collocated with the 172nd Infantry Brigade (Separate) at Fort Wainwright and its aviation assets, for both tactical and garrison operations, observes the atmosphere and evaluates, then tailors, forecast products to produce Mission Execution Forecasts and staff briefings. The Alaska Army National Guard operates the airfield at Fort Richardson.

Figure 3-DOD-17. CH-47 Chinook helicopters depart Bagram Airfield in support of military operations in Afghanistan (United States Army photo).

United States Army Forces Command (FORSCOM)

Weather support to the United States Army Forces Command (FORSCOM) is diverse and demanding. FORSCOM, the Army's largest major command, requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 760,000 Active Army (AA), United States Army Reserve and Army National Guard (ARNG) soldiers. These soldiers account for approximately 85 per cent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide (Figure 3-DOD-17). The AA component of FORSCOM has nearly 200,000 soldiers. Third United States Army is the Army component of United States Central Command (USCENTCOM), which is the Joint command responsible for Southwest Asia (SWA) and the Horn of Africa. FORSCOM also commands two Army Corps: III Corps at Fort Hood, Texas, and XVIII Airborne Corps at Fort Bragg, North Carolina. Together they include six divisions, two armored cavalry regiments, five separate brigades, and a range of other corps combat, combat support, and combat service support units. Two Continental United States Armies (CONUSAs), First United States Army and Fifth United States Army, are responsible for training, mobilization, and deployment support to Reserve Component units in FORSCOM.

A major subordinate command to FORSCOM, the United States Army Reserve Command (USARC), commands all United States Army Reserve units in the continental United States except those assigned to Special Operations Command. FORSCOM's Army Reserve strength stands at approximately 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transportation, maintenance and supply.

The ARNG provides FORSCOM a

balanced force of eight National Guard combat divisions, 15 enhanced separate brigades, extensive combat support, and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

United States Army Signal Command also falls under control of FORSCOM and provides all Echelon Above Corps (EAC) tactical, power projection, and strategic signal support to warfighting unified commanders as well as Army component commanders, in both war and peace.

Weather support to FORSCOM's AA units comes from dedicated Air Force weather teams aligned under three Air Support Operations Groups (ASOGs): 1 ASOG at Fort Lewis, Washington; 3 ASOG at Fort Hood, Texas; and 18 ASOG at Pope AFB, North Carolina. A weather squadron for each ASOG makes up the Corps' CWT. Each Army division has their own dedicated CWT. These CWTs are aligned under an Air Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division CWTs are authorized enough personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81, Air Force Joint Pamphlet 15-127, Weather Support for Army Tactical Operations. Currently, there are nearly 350 Air Force weather authorizations supporting various echelons across FORSCOM. These Air Force Weather personnel provide garrison and tactical weather warning, observing, forecast, special support, and SWO services during peacetime, contingency, exercise, or armistice operations.

FORSCOM weather units provide direct, on-site support at 11 major installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana and at deployed locations. Support is focused on air, ground, special operations, other combat, and combat support missions.

FORSCOM provides supporting USAF units with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). Eleven artillery meteorological (ARTYMET) sections, comprised of Army weather personnel, collect upper air observations for direct use by field artillery units.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving graphics and alphanumeric data. Data is received via a Very Small Aperture Terminal (VSAT). The New Tactical Forecast System (tactical version of AMIS) is the primary equipment used for deployed locations with data received via Tactical-VSAT, the Non-Secure Internet Protocol Router Network and the Secure Internet Protocol Router Network. Satellite imagery (METEOSAT and Defense Meteorological Satellite Program) is received via the Small Tactical Terminal. Nineteen Integrated Meteorological Systems, developed by the Army Research Laboratory, have been fielded within FORSCOM. FORSCOM has fielded commercial Automated Weather Observing Systems at Yakima Training Center Washington, Fort Campbell, Kentucky, and Georgetown Bahamas.

Training and Doctrine Command (TRADOC) Programs

HQ TRADOC is responsible for development and management of weather training programs, Army and Joint weather support doctrine (concepts and field manuals), and the establishment of requirement documents for Army tactical weather support. Headquarters, TRADOC is the approval authority for Army-AF weather doctrine, Army weather hardware requirements, and weather support policy. Key mission area for the next few years will be to coordinate weather requirements during Air Force Weather Reengineering and Army Transformation. The Army Tactical Experiment 2002 (ATEx 02) in Fall 2002 will test new concepts in deployed weather support to the prototype Army Brigade Combat Team.

The Integrated Meteorological System (IMETS) continues as the state of the art weather forecast system, but 2002 marked the start of deployment of the laptop version of this system. Minimizing the footprint of deployed weather equipment and personnel contribute to the rapid deployability of these light and lethal Army forces, while leveraging weather intelligence to maintain Intelligence, Surveillance, Reconnaissance (ISR) overmatch.

The Schools and Battle Laboratories

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the warfighter by developing solutions to satisfy Army weather requirements. In addition, it serves as the proponent for the *Owning the Weather* (OTW) program - a concept for exploiting weather as a force multiplier on the battlefield. The key component to OTW is IMETS, fielded by the Army and operated by Air Force CWTs.

The USAIC&FH Weather Support Team (WST) advises the USAIC&FH, ARL, and Air Force Weather (AFW) on Army weather support issues and helps develop solutions to meet both active and reserve forces' requirements. In addition, the WST monitors weather support training to Intelligence and AFW personnel supporting the Army (e.g., the Staff Weather Officer Army Indoctrination Course), and establishes requirements documents for weather support equipment.

Over the last year, the WST continued to update and expand the weather

effects critical threshold value database to be incorporated into the Integrated Weather Effects Decision Aid (IWEDA). The WST participated in the ongoing Army Force XXI and AFW Reengineering process and programs. Finally, they updated the Operational Requirements Document (ORD) for IMETS.

The Air Force staff weather officer at the Army's Combined Arms Center (CAC) is the primary overseer of the Tables of Organization and Equipment for CWTs supporting Army operations. The CAC SWO also arranges for and provides environmental data, concepts of operation, and weather support guidance for various programs, projects, and studies conducted by the TRADOC System Manager for Army Battle Command System, the Battle Command Battle Laboratory-Leavenworth, and the TRADOC Analysis Center. Development of weather scripts and climatological packages to support modeling and simulation exercises of the Battle Command Training Program (BCTP), the Command and General Staff College (CGSC), and the National Simulation Center at Fort Leavenworth is another key CAC SWO task.

The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the Army. Artillery meteorological crews, Active and Reserve, currently use the AN/TMQ-50 to measure surface weather parameters, and the AN/TMQ-41 Meteorological Measuring Set (MMS) to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF CWTs for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. (Army will be working with USAFAS to ensure these surface and upper air observations are sent back to weather centrals where they can be ingested in to our newest mesoscale models.) Over the next few years, the MMS will be replaced by an atmospheric sounder system. The sounder can take upper air observations more rapidly and accurately and preclude the logistical burden of helium/hydrogen balloon-based systems.

The Engineer School (USAES), Fort Leonard Wood, Missouri, coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full-time civilian meteorologist in the Terrain Visualization Center, DCD, but now has an instructor at the terrain school at Fort Belvoir, Virginia, to teach weather effects on cross-country mobility and engineer missions. (Operating Location B, 3rd Weather Squadron, USAF, provides weather observation services at Forney Army Airfield, Fort Leonard Wood, Missouri. OL-B is included in this report only to the extent that Fort Leonard Wood provides funding for its expendables and overhead.) In 1999, the Army Military Police and Chemical Schools moved to Fort Leonard Wood. Neither currently employ meteorologists.

The Aviation Center at Fort Rucker, Alabama, incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites. In FY 2003, Air Combat Command plans to civilianize most weather support to Aviation operations at Fort Rucker and surrounding satellite airfields. Four active duty positions are allocated to provide support to curriculum, and concept development at the Aviation School.

LOCATION	BASE	MILITARY	CIVILIAN	TOTAL
Virginia	Fort Belvoir	5	0	5
Georgia	Fort Benning	7	0	7
Kentucky	Fort Knox	5	0	5
Missouri	Fort Leonard Wood	0	3	3
Oklahoma	Fort Sill	5	0	5
Arizona	LibbyArmy Airfield	1	3	4
Alabama	Fort Rucker	13	0	13
Alabama	Andalusia	2	0	2
Alabama	Troy Municipal Arpt	0	2	2
TOTAL		38	8	46

Table 3.2 Planned outsourcing of weather positions.

The weather units at Fort Benning, Fort Knox, and Fort Huachuca provide airfield observing and forecast support to their respective Army posts.

During 2003, as directed by the Air Force Chief of Staff, the weather forecasting and observing functions at several TRADOC posts will be outsourced. This direct conversion

impacts a total of 8 civilians and 38 military at 9 locations as shown in Table 3.2.

Army National Guard (ARNG) Artillery

The Army National Guard (ARNG) has 48 Meteorological Sections assigned to artillery units at Division level, Field Artillery Brigades, and in Separate Brigades. The ARTYMET sections provide upper air observations at least 39 training days each year supporting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTYMET sections support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG is in the process of modernizing to the Meteorological Measuring Set (MMS), AN/TMQ-41A.

Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) uses a network of about 8,810 land-based gauges. About 55 percent of the sites collect meteorological data, 35 per cent a combination of hydrologic and meteorological data, and 10 per cent hydrologic or water quality data. The Corps funds or partially funds 61 percent (4,500) of all the gauges it used. Meteorological gauges commonly measure minimum of precipitation, temperature as a minimum. Most sites also measure hydrological data. All data are used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/NWS to collect and maintain precipitation information from 600 of meteorological sites. Similarly, COE transfers funds to the United States Geological Survey to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Eight-two per cent of all Corps sites provide real-time via satellite microwaves meterbursts, landlines or radio. Data from all COE networks are available and used by other federal, state and local agencies.

United States Army Space and Missile Defense Command (USASMDC)

Army Space Command (ARSPACE), an USASMDC component, provides operational space weather support on a limited basis to Army units through it's Army Space Support Teams (ARSST) as well as Space Operations Officers (FA40). Limited space weather support is provided to Army warfighters as part of ARSPACE's effort to improve overall space support and situational awareness. Potential space weather effects include disruptions of over the horizon communications, radar interference, space environment induced satellite service disruptions, high flyer radiation hazards and hazard warnings to civil power grids resulting from geomagnetic activity.

Related projects include the annually updated Space Weather Smart Book that is intended to improve the ARSPACE staff, ARSST teams and FA40s understanding of space weather fundamentals.

Force Development and Integration Center (FDIC), a part of USASMDC, is responsible for articulating space requirements including space weather. In addition, FDIC is responsible for development and execution of the Space Operations Officer's Qualification (SOOQ) Course that is the primary training tool for Space Operations Officers. Currently, the Space Weather portion consists of 3 hours of instruction titled, Impacts of Space Weather and Effects of Atmospheric Weather. Plans are being worked within FDIC to extend the SOOQ training concept to enlisted Army personnel and the Department of the Army Civilian workforce.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASMDC located on White Sands Missile Range, New Mexico, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HELSTF activities by providing atmospheric propagation and meteorological measurements, planning, and analysis as required. These capabilities also support the safe storage, handling and use of the toxic laser fuels.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support for the Ronald Reagan Ballistic Missile Defense Test Site (RTS). The RTS (Figure 3-DOD-18) meteorological services support contractor performs meteorological support for range activities including missile operations (GMD, TMD, ICBM) within the atoll, intra-atoll transportation (marine and aircraft), remote island missile launches including Wake Island (TMD), and severe tropical weather emergency center operations. Supporting these operations are local surface and upper air observations using five upper air sounding systems (two mobile), one polarimeteric-Doppler S-band radar,

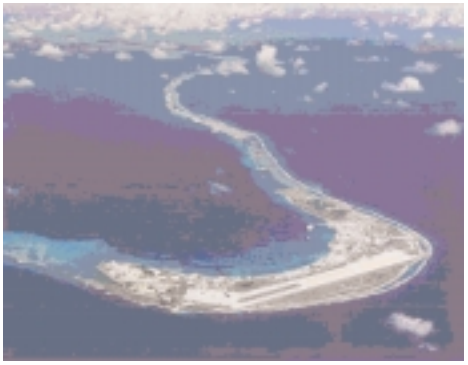

Figure 3-DOD-18. USASMDC is responsible for meteorological support to the Ronald Reagan Ballistic Missile Defense Test Site in the remote Kwajalein Atoll (United States Army photo).

one Doppler C-band radar, two DMSP/NOAA satellite receivers (one mobile) both having McIDAS display and management systems, one geostationary satellite receiver, and an intra-atoll mesonet with an automatic surface observation system at Roi-Namur airfield. In addition, RTS meteorological support in cooperation with NASA/GSFC is supporting global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement and a smaller program of monitoring the solar-earth radiation flux for NOAA/ERL.

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations.

Corps of Engineers (COE)

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by two COE laboratories: topographic Engineering Center (TEC) and the Cold Regions Research and Engineering Laboratory (CRREL). TDAs interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. Critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology Demonstrations are currently being transitioned to terrain and weather systems such as the Integrated Meteorological System (IMETS), and the Digital Topographic Support System (DTSS).

The COE Topographic Engineering Center (TEC), Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This support includes the development and integration of environmental effects databases and models that are relevant to military plans, operations and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules that are designed to be exploited in the synthetic environment arena and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC also reviews all emerging materiel systems for environmental effects.

Under the military portion of its civil and military support mission, the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, provides weather support to Army weapon systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL conducts basic research in sensor signal interaction with snow, ice, and frozen soil, icing accretion on surfaces and structures, deicing technologies, and cold regions surface-air boundary process. CRREL develops databases and models predicting infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Other programs include weather effects on environmental research for military training lands, winter effects on acoustics, helicopter pre-flight deicing and airborne icing avoidance, remote sensing for predicting snow coverage and snow-water equivalence for snow melt runoff, and modeling winter effects for input into Army operational and training models and simulations.

Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather research and development responsibilities.

Within the Army Research Laboratory (ARL), the Army Research Office (ARO) manages the Army's extramural basic research program in the atmospheric sciences and the

Battlefield Environment (BE) Division is the lead DOD agency for research and development in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer.

BE's mission is to provide the technology and tools (1) for the Warfighter to know and exploit weather on the battlefield, (2) for the commander to avoid exposing the Soldier to environmental hazards, (3) for the Materiel Developer to quantify the atmospheric effects and minimize the weather impacts on developmental weapons systems, and (4) that improve the understanding and the underlying science of atmospheric processes at sufficiently high resolution and fidelity to address the close combat environments that will face the Army's future Objective Force. Within the DOD, BE is the lead agency for multi-service R&D programs in transport and dispersion modeling, boundary layer meteorology over land, and atmospheric effects on boundary layer acoustic and electro-optic propagation. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, modeling of boundary layer processes, and assessing atmospheric effects on military system performance. The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the AF, Navy, or civilian community, and over data-sparse geographic regions. While the AF provides the Army with its basic tactical weather support, the Army provides technology to support service-unique requirements and Army systems, as well as distributing this weather intelligence information to the Army Battle Command Systems (ABCS) on the battlefield.

The joint Army/AF tactical weather support systems require knowledge of current and forecast battlefield environmental conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute to achieving the Army's decisive advantage over its adversaries. The Army's atmospheric science R&D program is responding to a number of changing Army requirements and Air Force Weather initiatives. Support to higher command echelons will continue to emphasize forecasting weather and its projected military impacts up to one to five days in advance for mission planning. Army Transformation to light, highly mobile Combat Brigades, however, will emphasize continuous situational understanding and mission execution requiring a current picture of fine scale meteorological conditions for the close in battle. This transformation will require capabilities to assimilate and fuse meteorological information from local sensors, observations and remote sensing in near real-time. Some key information may not be in traditional weather observation format or acquired with standard sensors at standard levels.

The current Air Force Reengineering initiative is transforming future weather support to the Army through centralization of weather support and analysis at the Air Force Weather Agency (AFWA), Offutt AFB, Nebraska. In the future, Air Force/Army CWTs in the field and the Army systems that they support will need to rely more on global communications reach back to AFWA to obtain daily weather forecast data, METSAT data, and weather impact products. Limited bandwidth means that only the most essential data can be broadcast to the Army units. More automated post processing will be required of this core data at the field unit level, including local generation of weather-effects products, fusion of local weather observations and assimilation of remote sensing information.

The BE Division within the ARL Computational and Information Sciences Directorate, consists of three branches and two centers. These span the two BE Division sites at Adelphi, Maryland, and White Sand Missile Range, New Mexico. The three branches combine basic and applied research programs in the areas of atmospheric aerosols and contaminants, chemical/biological transport and dispersion, planetary boundary layer processes, and atmospheric investigations. The two centers focus on establishing university and external laboratory partnerships and providing technology transition of ARL products for support of Army RDTE on weapons systems and weather information technology for tactical command and control and field artillery systems.

The Atmospheric Investigations Branch performs field measurements of the atmosphere, its processes and effects. BE opened an experimental site at Blossom Point, Maryland, in mid-1998, in a complex littoral region on the north shore of the Potomac River, and is able to conduct field experiments in electro-optic and acoustic propagation, as well as test weather modeling tools. Measurements at White Sands are performed at the lab and at the High Energy Laser Test Facility on the range.

The Atmospheric Effects Branch provides basic research and applies theories, laboratory measurements and field studies to produce innovative models, databases and new techniques that quantify the atmosphere and its effects on electro-optical and acoustic propagation, military systems and operations. This includes R&D to characterize simple and complex battlefield atmosphere obscurants, aerosols, gasses, liquids, particles, and various chemical and biological agents. These significantly reduce military system performance or exhibit signatures that are typically small, complex and difficult to distinguish relative to the natural background environment. A range of acoustic propagation models are developed and verified to treat the propagation of

acoustic spectral signatures through the atmosphere, including complex 3-D meteorological profiles, atmospheric scattering, ground impedance, and non-uniform terrain effects. Spectral emission, absorption, extinction, fluorescence, inelastic scattering, changes in polarization, turbulence effects and non-linear propagation are modeled and measured to improve intelligence and understanding through the battlefield atmosphere and to mitigate adverse effects and unwanted signals.

The Boundary Layer Meteorology Branch conducts a research program in the micrometeorological processes and structure of the atmospheric boundary layer. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes and the modeling of aerosol and chemical-biological transport and dispersion in the tactical environment including urban domains. A range of numerical weather models is addressed, including hydrostatic, non-hydrostatic and diagnostic gridded meteorological models. These are verified against existing numerical weather prediction models and data.

The Atmospheric Investigations Branch addresses improved methods to measure the atmosphere and its processes, to acquire tactical weather data, perform information assimilation and distribution. It includes exploitation of commercial and military satellite technology. The gridded meteorological databases support Army command and control systems and field artillery. Rule-based tactical decision aids for impacts of weather on military systems, platforms and operations are produced based on validated Army weather requirements. Software products are analyzed, verified and delivered for integration into the Army's Integrated Meteorological System (IMETS). IMETS is the weather INTEL functional area of the Army Battle Command Systems.

Research is also underway in enabling technologies that will permit the handling and transfer of large met data sets over the distributed, net centric force of the future.

The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of special funding are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (DEPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. At the Army Research Office, funding for basic research remains relatively static. Increased funding will come if special program initiatives or requests are approved. A primary focus continues on the analysis and understanding of data taken in the CASES99 field study of the stable boundary layer.

The following Communications Electronics Command (CECOM) organizations provide support to developing and fielding weather programs: Logistics Readiness Center (LRC), Research, Development and Engineering Center (RDEC), Software Engineering Center (SEC), and Safety office. The CECOM Logistic Readiness Center (LRC) is the level II manager of the Meteorological Measuring Set (MMS) program. CECOM RDEC's Intelligence and Information Warfare Directorate provides technical management and support to the Program Manager, Intelligence and Effects and Program Manager, Night Vision/Reconnaissance, Surveillance, and Target Acquisition for the Integrated Meteorological System (IMETS) and the MMS-Profiler. A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set (MMS), AN/TMQ-41. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). All active Army units are equipped with the MMS. In FY 1999, MMS production and fielding started and will continue through FY 2003 to modernize the National Guard.

The Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52 System. The Meteorological Measurement Set-Profiler (MMS-P) is

a major improvement over the MMS. The AN/TMQ-52 design will support the new generation of artillery weapons. The system will include frequent and update meteorological messages that enhances the meteorological validity over a larger battle space than the current equipment. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, radiosondes, and satellite-based sources, (such as boundary data from communications satellites and, in a future program block improvement, polar orbiting meteorological satellites) through onboard satellite receiving capability. The data affects the operation of the mesoscale meteorological model and for post-processing of the data in order to generate meteorological messages. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Currently in development are four System Design and Development (SDD) models. Development and testing is on schedule for FY 2002 and FY 2003 along with a scheduled production decision for FY 2003.

The Integrated Meteorological System (IMETS), Vehicle Mounted Configuration (AN/TMQ-40B/C) & Light Configuration (AN/GMQ-36). The Integrated Meteorological System (IMETS) is the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). The IMETS provides commanders at all echelons with an automated tactical weather system that receives, processes, and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas (BFAs). IMETS receives weather information from polar-orbiting civilian and defense meteorological satellites; civilian forecast centers, the Air Force Weather Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific warfighter's needs. The most significant weather and environmental support to warfighters are the automated tactical decision aids. These graphics display the impact of the weather on current or planned operations for both friendly and enemy forces. The warfighter can effectively employ his forces and weapons systems to achieve success in battle.

FY 2002 efforts will focus on four main areas. The Army will field one AN/TMQ-40C vehicle mounted configuration and complete the upgrade of twenty fielded IMETS from AN/TMQ-40A's to AN/TMQ-40B. The Army will also hand-receipt a second IMETS Light to the Interim Brigade Combat Team (IBCT) and will conduct an IMETS Light combined developmental and operational test in order to achieve a Milestone III decision for fielding this configuration.

In FY 2003 the army will field one AN/TMQ-40C vehicle mounted configuration and twenty-six AN/GMQ-36 Light configurations with one designated for the IBCT.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of United States Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to eight Army ranges and test sites. Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD research, development, test and evaluation (RDT&E) activities at the eight Army installations. Funding for the Army RDT&E Meteorology Program under Program Element 665702 has stabilized after several years of decline and is sufficient to maintain the basic meteorological support infrastructure at Army RDT&E ranges and sites. However, instrumentation needed to support unique or test-specific requirements generally must be funded by test sponsors.

The Army RDT&E Meteorology Program has entered into a multi-year working relationship with the National Center for Atmospheric Research (NCAR) to enhance "range scale" (mesoscale to microscale) forecast and analysis technology. The principal product of this relationship is the Four-Dimensional Weather (4DWX) System, which consists of a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model, and a variety of user-configurable displays. The MM5 mesoscale model is used operationally in both predictive and analysis modes to provide detailed information about the past, current, and forecast structure of the atmosphere over the Army's test ranges. Output from both MM5 forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology and

Obscurants Division at Dugway Proving Ground's West Desert Test Center serves as the Program Manager for Meteorological Support to Army RDT&E. Under Program Element 0605384, the Division's Modeling and Assessment Branch also provides the following specialized services: (1) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; (2) chemical/biological threat analysis, detection, and decontamination tests and studies for the Joint Contact Point (Project DO49); and (3) prototype development of virtual proving ground meteorological support. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and chemical/biological hazard assessment.

Army Medical Research and Materiel Command

The United States Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude, and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather-related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days.

The Operational Medicine Environmental Grid Applications (OMEGA) project is a software development effort intended to provide an integrated research platform for the evaluation of predictive modeling strategies for warfighters. It enables the integration of digital terrain data and real-time weather information with candidate physiologically-based environmental injury risk and performance prediction models. This test-bed system has a field of view of up to 200 X 200 kilometers and uses a color-coded map overlay display format. The web-enabled client-server architecture and archiving resources of OMEGA are intended to provide a rich and extensible tool set for model development efforts at USARIEM and to contribute key modeling methodologies directly to other projects.

The environmental Heat Stress Monitor (HSM), a pocket-sized electronic device, combines the USARIEM heat strain prediction model with a miniaturized sensor suite to measure air temperature, humidity, wind speed, solar radiation, and barometric pressure. This device provides tailored local guidance on optimal work/rest cycle limits, safe work time, and hourly drinking water needs for a wide range of military clothing types and work categories.

As part of the warfighter physiological status monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near term environmental strain and performance status predictions for individual warfighters. Research efforts in this area are intended to address capabilities identified in the Operational Requirements Document (ORD) for the Army's Land Warrior program.

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. A Phase II Small Business Innovative Research (SBIR) project to design and build a very small wireless network-capable, expendable, micro-environmental sensing system is underway, and the feasibility of on-body environmental sensors is also being investigated.